7 Detailed Analysis of Alternatives

This section presents the detailed analysis of the alternatives that were developed in Section 6. Each alternative was evaluated against the NCP threshold and balancing criteria. The CERCLA and NCP evaluation criteria and the general methodology used to perform the evaluations are summarized in Section 7.1. Sections 7.2 through 7.11 present the detailed analysis of Alternatives 1 through 10, respectively. The results of this detailed analysis were used to perform the comparative analysis of the alternatives presented in Section 8.

7.1 CERCLA and NCP Evaluation Criteria

CERCLA has statutory requirements that a remedial action must achieve and must be addressed in the ROD and supported by the FS. They are:

1. Be protective of human health and the environment;
2. Attain ARARs (or provide grounds for invoking a waiver);
3. Be cost-effective;
4. Utilize permanent solutions and alternative treatment technologies or resource recovery technologies, to the maximum extent practicable; and
5. Satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element or provide an explanation in the ROD as to why it does not.

The goal of the remedy selection process, as stated in 40 CFR 300.430(a)(1)(i) of the NCP, is to select remedies that protect human health and the environment, maintain protection over time, and minimize untreated waste. The NCP describes six expectations that EPA shall generally consider in developing remedial alternatives (see 40 CFR 300.430[a][1][iii][A–F] of the NCP):

1. Use treatment to address the principal threats posed by the site wherever practicable;
2. Use engineering controls, such as containment, for waste that poses a low long-term threat or where treatment is impracticable;
3. Use a combination of methods, as appropriate, to achieve protection of human health and the environment;
4. Use institutional controls, such as restrictions on groundwater use, to supplement engineering controls as appropriate, for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants;
5. Consider using innovative technologies when they offer the potential for comparable or superior treatment performance or implementability, fewer or

lesser adverse impacts than other available approaches, or lower costs for similar levels of performance, than demonstrated technologies; and

6. Return usable groundwater to its beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site.

The NCP requires that each remedial alternative be evaluated against nine criteria listed in 40 CFR 300.430(e)(9). The nine evaluation criteria have been developed to address the CERCLA requirements and considerations, and to address the additional technical and policy considerations that have proven to be important for selecting among remedial alternatives. These evaluations support identification of the most appropriate alternative for implementation at the Site. The nine evaluation criteria listed below include two threshold, five balancing, and two modifying criteria established by EPA (1988a and 2005) to address the requirements of CERCLA and the NCP.

Threshold Criteria

1. Overall Protection of Human Health and the Environment; and
2. Compliance with ARARs.

Balancing Criteria

3. Long-Term Effectiveness and Permanence;
4. Reduction of Toxicity, Mobility, or Volume Through Treatment;
5. Short-Term Effectiveness;
6. Implementability; and
7. Cost.

Modifying Criteria

8. State (Support Agency) Acceptance; and
9. Community Acceptance.

Table 7-1 lists FS analysis factors for each evaluation criterion, as stated in EPA's RI/FS guidance document (EPA 1988a). The first seven criteria serve as the basis for the detailed analysis of alternatives in the FS. The two modifying criteria are evaluated by EPA at a later stage in the CERCLA process (Section 7.1.3). The NCP evaluation criteria and the general methodology used to perform the evaluations are discussed in detail below.

7.1.1 *Threshold Criteria*

This section discusses the CERCLA requirement that remedies selected for implementation <u>must</u> meet two statutory threshold criteria: 1) overall protection of human health and the environment and 2) compliance with ARARs.

7.1.1.1 Overall Protection of Human Health and the Environment

The NCP states that, *"alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term,* *from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling[1] exposures to levels established during development of remediation goals consistent with 40 CFR 300.430(e)(2)(i)."* The protectiveness criterion describes how the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment (Sections 4.2.2 and 4.2.3, respectively) are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. The overall protectiveness assessment under this criterion draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

In the detailed evaluation of each alternative, the Overall Protectiveness criterion will be rated as "No," or "Yes," based on consideration of whether: 1) all exposure pathways are mitigated; 2) the alternative has long-term effectiveness and permanence; 3) does not pose a high short-term risk; and 4) meets ARARs or is waived from the requirement for compliance with an ARAR. A brief justification for each rating will be provided.

7.1.1.2 Compliance with ARARs

This criterion assesses whether the alternative complies with the chemical-specific, action-specific, and location-specific ARARs and other "To Be Considered" (TBC) criteria, advisories, and guidance identified in Section 4 (see Tables 4-1 through 4-3). CERCLA requires that remedial actions comply with the substantive provisions of ARARs.

Whether the ARAR to meet MCLs in groundwater could be met by the implementation of any of the alternatives was evaluated based on the use of modeling. Refer to Section 6.2.4.1 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. The groundwater flow and contaminant fate and transport model was used to calculate the approximate aquifer volume that may contain groundwater with COC concentrations exceeding MCLs 100 years after completion of remedial construction. The groundwater model was used as a relative tool to compare alternatives with respect to progress toward achieving MCLs. Due to the high degree of uncertainty, model predictions should only be interpreted in a relative sense for comparative analysis of alternatives. Further, EPA views the groundwater model results as conservative for the following reasons:

- The baseline condition plumes that the model generates for all primary COCs in DNAPL (benzene, naphthalene, and benzo[a]pyrene) significantly exceed the plume boundaries based on empirical data. This is due, in part, to:
    - DNAPL source strength set as a constant over the 100-year plume propagation period;

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[1] "eliminating, reducing or controlling exposures…". Eliminating means contaminates are removed or treated; reducing means exposures to contaminates are based on containment; and controlling refers to the use of institutional controls. The distinction in the manner in which protectiveness is conferred by an alternative is important to ranking various alternatives to specific evaluation criteria.

    - Use of potentially conservative half-lives; and
    - Use of arithmetic averages of measured COC concentrations (as opposed to log-normal averages, which would result in lower initial concentrations).

- Given that coal tar/creosote production stopped in 1969 (45 years ago), it is reasonable to assume that the groundwater plumes are in steady state or reducing (i.e., they would not grow to the sizes predicted by the groundwater model). This is supported by groundwater data showing either steady or decreasing concentrations in shoreline monitoring wells (Figure 5.2-7 in the RI Report [Anchor QEA and Aspect, 2012]).

- Because the baseline-generated plumes are larger than empirically determined plumes, the predicted model outcomes (restoration time frames and resultant plume sizes) are also likely to be "larger" than actual outcomes. This infers the following:

    - Model-estimated restoration time frames are longer than the actual time frames would be.
    - Model-estimated plume volumes (based on incremental removal of source) are larger than the actual plume volumes would be.
    - This is especially important for Alternatives where all source materials are treated or removed (Alternatives 7 through 10).

        - For benzene and naphthalene, the remaining contaminant mass will flushed and the mass and thus groundwater concentrations of these COCs would decay over time based on their half-lives.

        - For benzo(a)pyrene, empirical data indicate a close association of MCL exceedances with the occurrence of DNAPL. The model baseline condition plume for benzo(a)pyrene includes areas outside of the DNAPL footprint with MCL exceedances, while empirical data show no exceedances.[2] Therefore, the model results show that, if the DNAPL source is removed, then there are still areas of the Site with MCL exceedances that would not significantly degrade overtime. Based on empirical data, if the DNAPL source is removed, then the benzo(a)pyrene plume should also be fully addressed.

[2] Note that there are a few instances of very low detections of benzo[a]pyrene above the MCL in areas outside the current DNAPL "footprint." In most cases, they are immediately outside the footprint or barely above the MCL (0.24 micrograms per liter in BH-29A, compared with the MCL of 0.2 micrograms per liter).

- For arsenic, treatment or removal of the DNAPL source is anticipated to affect a change in the subsurface reducing conditions that have enhanced arsenic mobility.

It cannot be known for certain whether MCLs can be met everywhere onsite within a reasonable time frame, even with the most aggressive alternatives. For example, the model does not account for the impact of residuals.[3] These may include:

- **Residuals from dredging**. EPA expects that dredging would be conducted in such a way as to minimize the generation of residuals. If generated, they would be highly diluted from their in situ pre-remedy concentrations because they would be more evenly mixed and spread out over the area being remediated. Even so, all alternatives that include dredging also include placement of reactive covers over dredged areas.

- **Residuals from in situ solidification**. It is expected that there will be a "halo" around the solidified area(s). The mobile benzene and naphthalene that leaches from the block(s) will be undergo degradation and will be dispersed and diluted in the groundwater. Because benzo(a)pyrene is essentially immobile, it will not likely leach from the block(s) or leach only a de minimis amount. EPA does not considered the solidified block as aquifer material; however the model assumes no change in groundwater concentrations in the block as a result of the solidification. This assumption most likely yields greatly over-stated initial post-remediation COC concentrations within the solidified areas and therefore greatly over-stated mass flux estimates that contribute to downgradient MCL exceedances and longer restoration timeframes.

- **Residuals from potentially not addressing every occurrence of DNAPL.** Although the lateral and vertical extent of PTW remediation in both the upland and aquatic areas of the Site will be based on a field performance standard (to be determined during remedial design), small volumes and masses of DNAPL residuals could be inadvertently missed during remedy implementation. DNAPL residuals would most likely be in very thin laterally discontinuous sand stringers within the Shallow Aquifer bounded by relatively impermeable silts/clay making them very low strength groundwater contamination sources. Naphthalene and benzene mass and thus groundwater concentrations would decay over time based on their half-lives. Benzo(a)pyrene would essentially not decay and would remain essentially immobile and not significantly contribute to dissolved groundwater contamination.

It is expected that best management practices would be used during remedy construction to address these issues related to residuals.

[3] EPA directed the Respondents to not consider residuals in the model because there are no data to reliably model the impact of residuals from dredging, excavation, *in situ* solidification, or contamination inadvertently left behind following the remedy.

In summary, although there are significant modeling uncertainties, it is still considered to be a very useful tool for evaluating and comparing the relative effectiveness of the alternatives, particularly with regard to achieving MCLs. For "Compliance with ARARs", the percent reduction of the plume volume for each COC with an MCL is used as a relative metric. Uncertainties with regard to the model results are further discussed for each alternative as appropriate. Figure 7-1 shows projected groundwater volumes exceeding MCLs for the individual COCs benzene, benzo(a)pyrene, and arsenic 100 years after completion of remedial actions.

In the detailed evaluation of each alternative, the Compliance with ARARs criterion will be rated as "No", "Yes with TI Waiver" or "Yes". A brief justification for each rating will be provided.

7.1.2 *Balancing Criteria*

Alternatives that satisfy both of the threshold criteria are then evaluated using the five balancing criteria[4]. The five balancing criteria represent the main technical criteria upon which the alternative evaluation is based. Factors to be evaluated under each of the balancing criteria are discussed below.

7.1.2.1 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence are evaluated with respect to the magnitude of residual risk associated with waste left in place and the adequacy and reliability of controls used to manage remaining waste (untreated waste and treatment residuals) over the long-term. Alternatives that afford the highest degrees of long-term effectiveness and permanence are those that leave little or no waste remaining at the site such that long-term maintenance and monitoring and reliance on institutional controls are minimized. The components of this criterion include the following:

a. Magnitude of residual risk— risk remaining from untreated waste or treatment residuals left on-site after remedial action is completed.

   – The potential for this risk may be measured by numerical standards such as cancer risk levels or the volume or concentration of contaminants in waste, media, or treatment residuals remaining on the site. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate (EPA 1988a).

   – The volume of DNAPL removed or treated in each alternative was estimated using the Thiessen polygon areas shown on Figure 4-6. Consistent with Appendix G of the RI Report (Anchor QEA and Aspect 2012), DNAPL volume calculations for each polygon were based on the cumulative thickness

[4] The Quendall Terminals Superfund site has many recalcitrant COCs and a very complex subsurface. Both contribute to challenges in developing and selecting remedial alternatives that are appropriate to the site. An array of alternatives were developed to address the remedial problems at Quendall but it was uncertain prior to the evaluation of alternatives if any of the alternatives would satisfy threshold criteria and potentially require a waiver of ARARs. The FS process was conducted accordingly.

of PTW soil addressed by the alternative, and assumed a soil density of 1.6 tons/cy and a total hydrocarbon concentration of 34,000 milligrams per kilogram of PTW soil. Refer to engineering calculation sheets E-7 through E-15 in Appendix E of this FS for detailed calculations. Resulting DNAPL volumes, broken out by upland versus aquatic areas and by removal/treatment technologies, are summarized in Table 7-2. Site-wide DNAPL removal/treatment volumes for each alternative are presented on Figure 7-2 in the form of a bar chart. Table 7-2 also shows DNAPL removal/treatment estimates as a percentage of the total estimated DNAPL volume in the upland and aquatic areas, and Site-wide.

b. Adequacy and reliability of controls— used to manage treatment residuals or untreated wastes that remain at the site in the long-term and to determine if they are sufficient to ensure that any exposure to human and environmental receptors is within protective levels. Adequacy and reliability of controls can be assessed by examining the complexity and efficacy of requirements of long-term operation, maintenance, and monitoring of the alternative.

   – It also includes the assessment of the potential need to replace technical components of the alternative, such as a reactive materials within an amended cap or RCM, or a PRB treatment system; and the potential exposure pathway and the risks posed should the remedial technology require replacement.

   – The adequacy and reliability of institutional controls can be evaluated based on how they are implemented and maintained and on how the institutional controls would be enforced by the relevant agency or government entity.

7.1.2.2 Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances as their principal **element**, including the treatment of principal threats posed by the site. Analysis factors considered under this criterion include the following:

- Treatment processes used and materials treated;
- Amount of hazardous materials destroyed or treated (the vast majority of the contaminant mass at the Site is present as DNAPL or DNAPL-impacted soil or sediment [i.e., PTW]; therefore, this subcriterion is primarily evaluated based on the amount of PTW [as volume of DNAPL] that is treated);
- Degree of expected reductions in toxicity, mobility, and volume measured as a percentage of reduction (or order of magnitude);
- Degree to which treatment is irreversible;
- Type and quantity of residuals remaining after treatment; and
- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

Four types of PTW treatment are employed to various degrees in the range of alternatives: 1) off-site incineration of mobile DNAPL accumulating in collection trenches, 2) *in situ* solidification of upland PTW, 3) on-site thermal treatment of PTW, and 4) absorption of DNAPL by organoclay sediment caps. Treatment of dissolved-phase groundwater contamination that is a direct result of groundwater in contact with PTW, via PRBs, organoclay sediment caps, engineered sand caps, and/or pump and treat systems are also employed in many of the alternatives. The groundwater flow and contaminant fate and transport model described in Section 6.2.4.1 and Appendix A was used (as a relative tool) to predict the degree to which the contaminant plume and mass flux to sediments would be reduced, relative to Alternative 1, No Action, 100 years after completion of remedial construction (refer to Figures 7-1 and 7-3). Only mass contributed from upland contamination was considered. The alternatives that employ one or more of these treatment technologies will be evaluated using the factors listed above.

7.1.2.3 Short-Term Effectiveness

This criterion assesses effects and risks to human health and the environment until response objectives are achieved. Analysis factors considered under this criterion include the following:

- Protection of community during remedial actions—addresses any risk that results from implementation of the proposed remedial action, such as dust from excavation, transportation of hazardous materials, or air-quality impacts from a thermal treatment operation that may affect human health;
- Protection of workers during remedial actions—assesses threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken;
- Environmental impacts—addresses the potential adverse environmental impacts that may result from the construction and implementation of an alternative and evaluates the reliability of the available mitigation measures in preventing or reducing the potential impacts; and
- Time until RAOs are achieved.

All alternatives will require establishment and adherence to proper health and safety and construction planning documents and protocols.

7.1.2.4 Implementability

This criterion evaluates the ease or difficulty of implementing the remedial alternative by considering technical feasibility, administrative feasibility, and availability of services and materials required for implementation. Analysis factors considered under this criterion include the following:

- Technical feasibility (ability to construct and operate the technology; reliability of the technology; ease of undertaking additional remedial actions, if necessary; and ability to monitor effectiveness of remedy);
- Administrative feasibility (ability to obtain approvals from other agencies, and coordination with other agencies); and

- Availability of services and materials (availability of off-site treatment, storage, and disposal services and capacity; availability of necessary equipment and specialists; and availability of prospective technologies).

Appendix C (detailed technology/process option screening) evaluates the technical feasibility of implementing various Site remedial technology process options.

7.1.2.5 Cost

This criterion includes all direct and indirect capital costs as well as OM&M costs incurred over the life of the project (100-year project life assumed for cost estimating purposes). Appendix D provides detailed cost estimates for Alternatives 2 through 10. Two costs were calculated for each alternative: one using Net Present Value (NPV) analysis[5] assuming a discount rate of 7 percent, and one with no discount rate for future costs. NPV analysis allows costs for remedial alternatives to be compared on the basis of a single figure by discounting all future costs to a common base year. The NPV of a project represents the dollar amount which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. As stated in the RI/FS guidance (EPA 1988a), these estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent but do not account for post-FS changes in the scope of the remedial alternatives. Refer to Appendix D for additional information.

7.1.2.6 Alternative Rating with Respect to the Balancing Criteria

In the detailed evaluation of each alternative, the first four balancing criteria (all except "Cost") will be rated "low," "moderate," or "high," depending on the degree to which the alternative is judged to satisfy the criterion. A brief justification for the rating is also provided.

7.1.3 *Modifying Criteria*

State (Support Agency) and Tribal Acceptance assesses the technical and administrative issues raised by the supporting agencies about the alternatives.

Community Acceptance assesses issues and concerns raised by interested persons in the community about the potential remedial alternative. Note that these modifying criteria were not evaluated in this FS; they will be evaluated by EPA after compilation of public comments and input received on the Site Proposed Plan.

7.2 Detailed Evaluation of Alternative 1

The No Action alternative provides a baseline for comparing other alternatives. The No Action alternative does not include any remedial actions, monitoring, or institutional controls, and all contamination is left in place. .

7.2.1 *Overall Protection of Human Health and the Environment*

The No Action alternative provides no control of exposure to contaminated media on site and contaminated groundwater continues to migrate into the lake. The No Action alternative is not protective of human health and the environment. The baseline risk

[5] NPV analysis is referred to as present worth analysis in the RI/FS guidance (EPA 1988a).

assessments (see Section 3.7) identified unacceptable risks to both human and ecological receptors associated with Site contamination. All current risks would remain unabated under this alternative. Therefore, the No Action alternative does not satisfy the threshold criterion of Overall Protection of Human Health and the Environment.

7.2.2 *Compliance with ARARs*

Additionally, because no action is being taken, ARARs such as the MCL for benzene, B[a]pyrene and arsenic will not be met and ambient water quality standards will not be met for all relevant COCs. Therefore, the No Action alternative does not satisfy the threshold criterion of Compliance with ARARs.

7.2.3 *Long-term Effectiveness and Permanence*

Alternative 1, No Action, does not include controls for limiting exposure and has no long-term management measures. The baseline risk assessments (see Section 3.7) identified unacceptable risks to both human and ecological receptors associated with Site contamination. These risks are not reduced by Alternative 1, No Action.

7.2.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

Alternative 1 does not include treatment as a remedial action. There is no reduction in toxicity, mobility, or volume of contaminated soils, groundwater, sediment or surface water.

7.2.5 *Short-term Effectiveness*

There are no additional risks to the community, workers or the environment because Alternative 1 does not include any remedial activities.

7.2.6 *Implementability*

There are no implementability concerns because no remedial action is being implemented under Alternative 1.

7.2.7 *Cost*

There is no cost associated with Alternative 1 because no remedial action is being taken.

7.3 Detailed Evaluation of Alternative 2

Alternative 2 focuses on containment through the use of an upland soil cap, RCM sediment caps over DNAPL containing sediment, engineered sand cap over sediments affected by upwelling contaminated groundwater, and ENR over sediments exceeding the BTV for cPAHs. Alternative 2 includes reliance on institutional controls to prevent exposure to contaminated media. This alternative includes maintenance and monitoring of engineering controls to ensure that exposure pathways are controlled and cleanup numbers are achieved in perpetuity. Refer to Section 6.3.2 for a detailed description.

7.3.1 *Overall Protection of Human Health and the Environment*

Alternative 2 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.3.1.1) and the environment (Section 7.3.1.2) as follows:

7.3.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 2. None of the PTW that causes the groundwater contamination is removed or treated in this alternative. Overall, the groundwater plume would be reduced by 11 percent as compared to Alternative 1 (No Action). Human health risks would be addressed by institutional controls that would prohibit use of groundwater for drinking water purposes and construction of wells for any purpose, including domestic uses (e.g., inhalation while showering). This institutional control would remain in effect in perpetuity.

  Future sources of drinking water and other domestic uses will be addressed by use of the in place public water system operated by the City of Renton.

- **HH2: Reduce Risks to Recreational and Subsistence Consumers of Fish and Shellfish to Acceptable Levels.** Human health risk from recreational and subsistence ingestion of resident fish and shellfish taken from the Site would be reduced and controlled by the use of engineered sand and RCM caps, ENR, and institutional controls. Alternative 2 would initially reduce COC concentrations in surface sediments which, in turn, would reduce the levels of COCs in resident fish and shellfish to acceptable levels. Human health risks would be addressed by institutional controls to aid in preventing exposures and monitoring and maintenance would provide information that the controls are functioning as required. Monitoring and maintenance of all caps and ENR (inspection/repair program) would remain in place in perpetuity to ensure integrity of the caps and ENR.

- **HH3: Reduce Risks to Recreational Beach Users From Exposure to Surface Sediment to Acceptable Levels.** Human health risk from playing, wading, or swimming resulting in incidental ingestion and/or dermal exposure to contaminated sediments would be reduced and controlled by the use of engineered sand and RCM caps, and institutional controls. Alternative 2 would reduce COC concentrations in surface sediments to acceptable levels. Sediment caps would reduce adult and child exposure to contaminated surface sediments. Institutional controls would control exposure to contaminated sediment by restricting activities that could cause damage to the caps and result in the release of contamination. Monitoring and maintenance of caps would remain in place in perpetuity to ensure the integrity of the caps.

- **HH4: Reduce Risks to Recreational Beach Users From Exposure to Surface Water to Acceptable Levels.** Human health risk from direct contact or incidental ingestion of surface water while playing, wading or swimming in contaminated surface water would be reduced and controlled through a combination of engineered sand and RCM caps, and institutional controls. Sediment caps would reduce upwelling contaminated groundwater through sediments to acceptable levels. Institutional controls would control exposure to contaminated surface water by restricting activities that could cause damage to sediments caps that mitigate the release of contamination into surface water. Monitoring and maintenance of caps would remain in place in perpetuity to ensure the integrity of the caps.

- **HH5: Reduce Risk to Future Residents from Exposure to Indoor Vapors to Acceptable Levels.** Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs would be reduced and controlled to acceptable levels by a soil cap and institutional controls. A soil cap could reduce possible future indoor exposures to vapors. Institutional controls, however, would require that any future use that results in human occupation in enclosed spaces will require an assessment for potential vapor intrusion risks and, if necessary, require engineering controls to eliminate exposure to vapors. Indoor air monitoring and maintenance of vapor control devices will be required in perpetuity.

- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Human health risk from direct contact or incidental ingestion of COCs in soil would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. The magnitude of contamination in surface soils would be reduced by the application of "clean" soil over contaminated surface soil. Institutional controls would control the disturbance of the soil cap from potential invasive activities (e.g., utility installation, gardening activities) by providing instructions and coordination of activities with EPA. Periodic inspection/repair of the soil cap would ensure the long-term cap integrity of the cap. The institutional controls and cap inspection/repair program would remain in place in perpetuity until soil exposure no longer poses an unacceptable risk (e.g., future development permanently and effectively prevents exposure to soil).

7.3.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels**. Risk to aquatic-dependent organisms when direct contact with surface water or incidental ingestion of COCs in surface water would be reduced or controlled to acceptable levels (water quality standards). Alternative 2 would reduce COC concentrations in surface sediments, which in turn would reduce the levels of COCs in surface water, through a combination of engineered sand and RCM caps, and ENR. Additionally, RCM caps and engineered sediment caps would reduce upwelling contaminated groundwater migrating through sediments to acceptable levels in porewater and surface water. Institutional controls would control exposure to contaminated surface water by restricting activities that could cause damage to sediments caps that mitigate the release of contamination into surface water. Monitoring and maintenance of caps would remain in place in perpetuity to ensure the integrity of the caps.

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels**. Risk to terrestrial wildlife from direct contact or incidental ingestion of COCs in soil or consumption of soil invertebrates containing COCs would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. The magnitude of contamination in surface soils would be reduced by the application of "clean" soil over contaminated surface soil. In the case of Alternative 2, the entire upland surface would require capping or soil data could be gathered to determine the extent of capping. Institutional controls would control the disturbance of the soil cap from activities that may comprise the integrity of the soil cap. Periodic inspection/repair to the soil cap would ensure the long-term cap integrity of the cap. The institutional controls and cap inspection/repair program would remain in place impurity until soil exposure no longer poses an unacceptable risk (e.g., future development permanently and effectively prevents exposure to soil).

- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Risk to aquatic-dependent wildlife (sediment probing birds and piscivorous mammals) and benthos resulting in incidental ingestion and/or direct contact to contaminated sediments or other aquatic organisms would be reduced and controlled by the use of engineered sand and RCM caps, ENR, and institutional controls. Alternative 2 would reduce COC concentrations in surface sediments to acceptable levels. Sediment caps would reduce exposure to contaminated surface sediments by providing a "clean" surface. ENR would reduce benthic exposure to contaminant levels in surface sediments. Institutional controls would control exposure to contaminated sediment by restricting activities that could cause damage to the caps or ENR coverage and result in the release of contamination. Monitoring and maintenance of caps would remain in place in perpetuity to ensure the integrity of the caps.

7.3.1.3 Alternative 2 Rating with Respect to this Criterion

Alternative 2 does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated "high" for Short-Term Effectiveness (Section 7.3.5); however, the alternative is rated "low" for Long-Term Effectiveness and Permanence (Section 7.3.3). The RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor is a candidate for a TI waiver (Section 7.3.2).

7.3.2 *Compliance with ARARs*

Alternative 2 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. None of the PTW that causes the groundwater contamination is removed or treated in this alternative. The extent to which MCLs would be achieved in this alternative is discussed below.

7.3.2.1 Compliance with the MCL ARAR

For Alternative 2, the groundwater volume exceeding MCLs is predicted to decrease by 14 percent for benzene, 1 percent for benzo(a)pyrene and 1 percent for arsenic (assuming an impermeable upland soil cap[6] relative to the No Action alternative) 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 2, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by 13 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.3.2.2 Technical Impracticability Waiver

It is assumed that Alternative 2 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTW is readily accessible and removal or treatment is feasible with currently available engineering technology.

7.3.2.3 Alternative 2 Rating with Respect to this Criterion

Alternative 2 does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.3.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 2 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.3.3.1 Magnitude of Residual Risks

In this subsection, the magnitude of residual risks associated with untreated waste/ treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

All PTW is left in place as untreated waste; therefore, DNAPL-impacted soils and sediment remain in place and untreated at 30,500 and 58,300 cy, respectively. The dissolved- phase plume exceeding the MCL ARARs and drinking water RBC are reduced (benzene at 14 percent, naphthalene at 10 percent, benzo(a)pyrene at 1 percent, and arsenic at 1 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.3.3.2 Adequacy and Reliability of Controls

Controls in Alternative 2 include an upland soil cap, sediment caps (engineered sand cap and RCM), ENR, institutional controls, and monitoring. The adequacy and reliability of

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[6] The alternatives were evaluated for compliance with MCLs assuming an upland impermeable cap, which would be consistent with future development plans. Modeling results indicate that plume reduction is small regardless whether an impermeable soil cap is used or a permeable soil cap. For the purposes of the FS, all Alternatives incorporate a permeable soil cap even though modeling assumed an impermeable soil cap because future development is expected to be likely and would include impermeable surfaces, primarily.

each of these controls are discussed below. Adequacy and reliability of controls can be assessed by examining the complexity and efficacy of requirements for long-term operation, maintenance and monitoring of the alternative.

Upland Soil Cap: An upland soil cap would be effective and reliable for preventing dermal contact and incidental ingestion of COCs in soil by residents, commercial workers and excavation/construction workers. Soil caps have been used routinely at Superfund sites to prevent exposure. The upland soil cap will remain effective if maintained properly (e.g., easy to repair/replace, monitor for remedial specifications, etc. Institutional controls needed to prevent intentional disturbance of soil caps covering contaminated soils.

Engineered Sand Caps. Engineered sand caps would be effective and reliable for protecting the benthic community and preventing dermal contact or incidental ingestion by swimmers or waders to surface water/porewater contaminated with COCs. The engineered sand cap would attenuate contaminated upwelling groundwater to safe levels. Engineered caps have a long history of use for successfully controlling contamination in sediment porewater. The caps will remain effective in perpetuity if maintained properly. Institutional controls will be required to restrict/prohibit activities that may compromise the integrity of the caps, such as prop wash. Long-term monitoring will be required to assess the concentrations of COC in sediment porewater in the area covered by the engineered sand cap in perpetuity.

RCM Caps. The adequacy and reliability of RCM caps is difficult to predict because the technology is relatively new. There is little field information about long-term effectiveness and reliability of RCM caps. There is no field information about how RCM placement and replacement/repair may affect the long-term viability of the RCM caps. The lack of long-term field experience and the need for treatability/pilot studies is a significant concern about the reliability of a technology that will be required in perpetuity. There is considerable debris on and in the surface sediments at Quendall that may cause problems with RCM integrity unless the sediment is sufficiently cleared of debris. The shoreline bathymetry would be required to be maintained, which may limit repair and replacement options. RCM caps may lose their effectiveness when the reactive material becomes saturated or damaged. Long-term monitoring and maintenance of RCM caps and maintenance and enforcement of institutional controls would be necessary, in perpetuity, to ensure effectiveness.

ENR. The purpose of ENR is to provide a clean sediment surface in locations where contaminant concentrations are low. ENR has been used previously at other Superfund sites and have been shown to be adequate and reliable in facilitating the re-establishment of benthic organisms, by the placement of a thin layer of clean sand and accelerating the process of physical isolation by natural sediment deposition. Long-term monitoring and placement of additional sand on an as-needed basis would ensure that contaminant concentrations in surface sediments remain at acceptable levels. Because the area to which the ENR would be applied is based on a cPAH BTV[7], evaluation of cPAH concentrations over time would be required in perpetuity.

Institutional Controls. Because all of PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, institutional controls would be required and relied upon in perpetuity. Proprietary controls (e.g., covenants to protect remedy components and limit future land use) would be more reliably enforceable in the uplands as compared with the aquatic environment. Fishing/swimming/wading bans would rely on the willingness and capability of local authorities to monitor for compliance and take enforcement actions. Permits and consent decree requirements (such as engineering controls) are more reliable as they are enforceable by EPA under CERCLA.

7.3.3.3 Alternative 2 Rating with Respect to this Criterion

Alternative 2 is rated "low" with respect to long-term effectiveness and permanence because all PTW remains on-site and it relies wholly on capping and institutional controls to provide long-term protection.

7.3.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.3.4.1 Treatment Processes Used and Materials Treated

Alternative 2 includes the use of RCM caps to sorb DNAPL in the event that DNAPL is disturbed and migrates upward to the cap.

7.3.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 2, no DNAPL is treated. The amount of DNAPL that may be sorbed onto the RCM caps is unknown.

7.3.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 2 does not include any upland technologies that would reduce toxicity, mobility, or volume through treatment.

The aquatic RCM caps are expected to be effective at preventing DNAPL migration from underlying sediments into the surface waters of Lake Washington; however, under ordinary circumstances, only a negligible amount of DNAPL is expected to be controlled or immobilized by these RCM caps.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes would be reduced by 10, 8, 1, and less than 1 percent, respectively. Mass flux for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 27, 31, 27, and 5 percent, respectively.

7.3.4.4 Degree to which Treatment is Irreversible

Treatment of DNAPL using RCM caps containing organoclay would be irreversible by sorbing organic matter to the organoclay (Bullock 2009).

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[7] The protective cleanup level for sediment is below the surrounding anthropogenic background required.

7.3.4.5 Type and Quantity of Residuals Remaining after Treatment

The remedial approach described in this Alternative results in very little treatment of contaminated media from the Quendall Site. If RCM caps containing organoclay become saturated with DNAPL, the material would be removed and replaced. DNAPL-saturated organoclay would likely be treated by incineration. Therefore, no residuals absorbed by the RCM caps would remain on-site once the "spent" organoclay is removed; however, an unknown quantity of organoclay with sorbed contaminants could be present on-site in perpetuity.

7.3.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 2 does not satisfy the statutory preference for treatment as a primary element of the alternative because the majority of the alternative is based on containment and little PTW is treated.

7.3.4.7 Alternative 2 Rating with Respect to this Criterion

Alternative 2 is rated "low" with respect to reduction of toxicity, mobility, or volume through treatment. This alternative reduces contaminant mobility through a slight reduction in groundwater mass flux and reduces the potential mobility of DNAPL in surface sediments. However, only a negligible amount of the Site contamination would be treated.

7.3.5 *Short-Term Effectiveness*

Alternative 2 consists of capping upland surface soils and surface sediments. Also, dredging of some potentially contaminated sediments are included to accommodate capping in order to maintain the current sediment bathymetry.

7.3.5.1 Protection of Community during Remedial Actions

For Alternative 2, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 2,800 cy of potentially contaminated sediment;
2) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 2,800 cy of potentially contaminated sediment.
3) inhalation exposure of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and
4) inhalation exposure from the import and handling of clean or reactive material to cap/cover 29.4 acres of sediment.

No unacceptable health risks to the community are expected. This determination is based on the availability and use of BMPs and the amount of hazardous material handled on-site. Use of BMPs can mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet.

The community may be more concerned about activities that may negatively impact the local "quality of life"[8]. For example, construction activities including truck traffic may result in excessive noise, and traffic congestion. Remedial construction activities could cause negative visual impacts. The same BMPs and good housekeeping that are used to manage cleanup activities that may pose a risk to public health can also address many of the "quality of life" issues that may concern the neighboring community. Additionally, EPA will work with the community to discuss ways that "quality of life" disturbances can be mitigated. For example, remedial construction would be limited to routine Monday through Friday work hours.

7.3.5.2 Protection of Workers during Remedial Actions

For Alternative 2, potential risks to site workers include the same exposure pathways as those associated with the neighboring community. However, additional exposures to workers can result from their close proximity to sources of exposure. These additional exposure pathways not only include inhalation but also dermal exposure pathways. On-site workers may be exposed to greater COC concentrations or frequency of dermal exposure which may not be applicable to the nearby community, e.g., dermal contact with dredged contaminated sediment. Potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to dust potentially containing hazardous substances from upland site clearing and grading activities;
2) Inhalation and dermal exposure to potential contaminants in surface sediments during construction of sediment caps;
3) Inhalation and dermal exposure during dredging, handling and off-site transport by truck of 2,800 cy of potentially contaminated sediments;

No health risks to on-site workers is expected because of the very small amount of hazardous substances expected to be in the dredged sediments and on-site use of BMPs, protective gear and clothing. BMPs include management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet. Soil cap construction will not involve hazardous substances. Exposure of workers to dust and air emissions is not expected to be a concern because sources of exposure do not contain hazardous substances. Concerns about inhalation of dust can be controlled by the use of dust masks.

7.3.5.3 Environmental Impacts

Alternative 2 would involve relatively little construction and a correspondingly low overall potential for environmental impacts. Impacts to the environment could be caused by site grading, clearing, and capping of soil and sediments as well as some dredging activities. Dredging consists of removing 2800 cy of potentially contaminated sediments to then be handled on-site and transported off-site for disposal. Small amounts of "clean" material will be used to cover approximately 30 acres of sediment for ENR and capping.

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[8] Quality of life impacts generally refer to the potential for an alternative to impact aesthetics, odor and dust, traffic, and noise; activities that do not cause a risk but are an ignorance.

In the terrestrial environment, impacts to wildlife, typically present on-site, are expected to result in wildlife relocating to another area in the vicinity of Quendall during construction activities.

The limited shoreline dredging to offset cap construction could result in extremely localized, short-term acute water quality criteria exceedances. Monitoring would be performed to document turbidity and contaminant levels and BMPs may be modified if exceedances of specified criteria are recorded or anticipated. Short-term impacts associated with dredging clean sediments and cap placement would include possible minor effects on water quality. These impacts primarily consist of turbidity due to suspended clean dredged sediments and capping materials.

Capping and ENR will cause short-term impacts to the water column due to the material being placed and causing increased turbidity problems. Additionally, capping material can sink somewhat into the contaminated sediments being capped, especially if the sediments being capped are “soft”, and cause resuspension of contaminated sediments into the water column. Unlike dredging, caps can fail or become damaged and require repair or replacement causing additionally short-term impacts. In areas where capping or ENR occurs, the benthic community would be significantly altered and/or eliminated in the short term. Assuming concentrations are acceptable, recolonization would be expected within several months (McCabe et al. 1998).

Construction practices to prevent uplands activities from impacting the aquatic environment will be monitored and enforced by on-site EPA personnel.

7.3.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed within 0.7 months from initiation of remedial construction (Figure 7-5); however, not all RAOs (refer to Section 7.3.1) would be achieved at the end of the construction period. The RAO for restoring groundwater to its highest beneficial use is not expected to be achieved within 100 years. The RAOs to reduce risks to humans and aquatic wildlife from exposure to fish/shellfish are not expected to be met immediately, although caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.3.5.5 Alternative 2 Rating with Respect to this Criterion

Alternative 2 is rated “high” with respect to short-term effectiveness because it would involve relatively modest construction activities with limited in-water work (limited sediment dredging to offset cap placement). No unacceptable human health risks are expected to the community or site workers. Negative short-term environmental impacts are expected to the benthic community but recovery is expected.

7.3.6 *Implementability*

7.3.6.1 Technical Feasibility

Alternative 2 includes: 1) construction of an upland cap; 2) installation and maintenance/repair of engineered sand and RCM caps, and ENR covers; and 3) off-site disposal of potentially contaminated sediment. These remedial technologies are well understood technologies, have been widely used over a number of years, and are considered to be technically feasible for the Quendall site, with the exception of RCM caps (or as an alternative an amended sand cap). RCM and amended sand caps are relatively new technologies and will be required to be in place in perpetuity, as will the engineered sand cap. There is little field experience with the general use of RCM caps and especially, there is no field information/experience regarding the long-term use and long-term efficacy of RCM caps. There is no information about the expected longevity of RCM caps nor is there much experience with repairing/replacing RCMs when they become ineffective. Unusual technical challenges are expected when RCM caps are placed and repaired or replaced in the aquatic environment because they have only been in use for a short period of time. Amended sand caps are also a relatively new technology; however, concerns about the installation, repair and replacement of amended sand caps are less than with RCM caps. RCM caps especially require ongoing maintenance and repair, in perpetuity. Engineered sand caps are much more easily maintained and repaired and because of similar engineering and construction methods expected to be used for amended sand caps relative to engineered sand caps, it is assumed that amended sand caps will be less problematic to maintain and repair than RCM caps.

7.3.6.2 Administrative Feasibility

Alternative 2 is administratively feasible. Permits are not required for on-site remedial work. However, EPA oversight ensures that all substantive requirements are met. Coordination with numerous federal and state regulatory agencies, during remedial design, would be required to ensure that all ARARs (including ESA consultation and substantive compliance with Section 401 and 404 of the CWA), policies, regulations are met. Coordination with these agencies, by EPA, has become routine in the Puget Sound area of Washington. Little coordination is expected during remedial action because reasons for coordination would be addressed during remedial design. Implementation of Alternative 2 is expected to be administratively feasible.

Various institutional controls would need to be put in place with the appropriate authorities to ensure that sediment caps and the ENR areas are protected from activities or events that could compromise these remedial technologies. However, many of the institutional controls intended to protect aquatic remedial technologies are unenforceable (see Section 7.3.3.2 on Adequacy and Reliability of Controls).

7.3.6.3 Availability of Services and Materials

Necessary engineering and construction services are readily available with multiple experienced contractors procurable through competitive bidding, with the possible exception of services for RCM caps. Sufficient sand and gravel mine production capacity exists within 20 miles of the Site to supply the capping material.

7.3.6.4 Alternative 2 Rating with Respect to this Criterion

Alternative 2 is rated "moderate" with respect to implementability. While implementability is not expected to generally be problematic there are significant concerns about the successful use of RCM caps and to a lesser degree of amended sand caps, in perpetuity.

7.3.7 *Cost*

The estimated present worth cost of Alternative 2 is $26 million, including a projected $18 million for capital construction and $7.6 million (present worth) for OM&M.

7.4 Detailed Evaluation of Alternative 3

Alternative 3 is different from Alternative 2 (which relies solely on capping) in that, in addition to capping, it includes (1) *in situ* solidification of PTWs in the RR and MC-1 DNAPL Areas to address the deepest occurrences of DNAPL, which are a key source of contamination to the Deep Aquifer, (2) a DNAPL collection trench system to remove mobile PTWs from the shallow subsurface to further reduce the potential migration of DNAPL from the uplands to the lake sediments, and (3) a PRB to treat contaminated groundwater in the upland Shallow Aquifer as it migrates west toward the shoreline. Refer to Section 6.3.3 for a detailed description.

7.4.1 *Overall Protection of Human Health and the Environment*

Alternative 3 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.4.1.1) and the environment (Section 7.4.1.2) as follows:

7.4.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 3. Approximately 14 percent of the upland PTW that causes the groundwater contamination is addressed in this alternative. Treatment of shallow groundwater leaving the uplands and entering the lake using a PRB would restore an unknown amount of groundwater. Overall, the groundwater plume would be reduced by 28 percent as compared to Alternative 1 (No Action). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternative 2.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 2.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 2.

- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 2.

- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels**: Same as Alternative 2, except vapor intrusion would be reduced by a nominal amount due to *in situ* solidification of the PTWs in the MC-1 DNAPL Area. Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs throughout the Site would also be reduced and controlled to acceptable levels by soil caps and institutional controls. Treatment of the MC-1 DNAPL Area, which underlies the potential future location of mixed use buildings, would not reduce exposure to vapors sufficiently to reduce or change institutional controls, engineering controls or capping requirements for vapor intrusion as identified in Alternative 2.

- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Same as Alternative 2, except a very small area of the uplands will be treated or excavated. These areas may not require a cap. Human health risk from direct contact or incidental ingestion of COCs in soil would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. A total of approximately 17,500 cy of soil would be treated with *in situ* solidification and approximately 2,900 cy of soil would be excavated during construction of the DNAPL collection trenches and the funnel and gate systems. It is assume that excavated PTWs and associated contaminated soil will be disposed at a RCRA Subtitle C Landfill.

7.4.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 2.
- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 2.
- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 2.

7.4.1.3 Alternative 3 Rating with Respect to this Criterion

Alternative 3 does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated "high" for Short-Term Effectiveness (Section 7.4.5); however, the alternative is rated "low" for Long-Term Effectiveness and Permanence (Section 7.4.3). The RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor is it a candidate for a TI waiver (Section 7.4.2). Protectiveness would be addressed via institutional controls and monitoring.

7.4.2 *Compliance with ARARs*

Alternative 3 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. Approximately 12 percent of the PTW that causes the groundwater contamination is removed or treated in this alternative. The extent to which MCLs would be achieved in this alternative is discussed below.

7.4.2.1 Compliance with the MCL ARAR

For Alternative 3, groundwater volume exceeding MCLs is predicted to decrease by 37 percent for benzene, 13 percent for benzo(a)pyrene and 5 percent for arsenic, relative to the No Action alternative, 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 3, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by 33 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.4.2.2 Technical Impracticability Waiver

It is assumed that Alternative 3 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTWs are readily accessible and removal or treatment is feasible with currently available engineering technology.

7.4.2.3 Alternative 3 Rating with Respect to this Criterion

Alternative 3 does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.4.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 3 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.4.3.1 Magnitude of Residual Risks

In this subsection, the magnitude of residual risks associated with untreated waste/ treatment residuals left on-site after remediation is presented in terms of the degree to which PTW sources are remediated and the percent the plume is reduced.

Approximately 88 percent (by volume) of the PTW is left in place as untreated waste; therefore, DNAPL-impacted soils and sediment remain at 24,600 and 55,100 cy, respectively. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBCs are reduced (benzene at 37 percent, naphthalene at 26 percent, benzo[a]pyrene at 13 percent, and arsenic at 5 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.4.3.2 Adequacy and Reliability of Controls

Controls in Alternative 3 include an upland cap, DNAPL collection trenches, a PRB (funnel and gate system), sediment caps (engineered sand cap and RCM caps), ENR, institutional controls, and monitoring.

Adequacy and reliability of controls can be assessed by examining the complexity and efficacy of requirements for long-term operation, maintenance and monitoring of the alternative. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternative 2.

DNAPL Collection Trenches. Properly designed DNAPL collection trenches would be adequate and reliable in limiting a small unknown volume of DNAPL migration from the upland portion of the Site to the lake, and in protecting the downgradient PRB treatment media from clogging with DNAPL. However, much of the mobile DNAPL at the Site is located in the QP-U area, which is downgradient of the collection trenches and PRB. DNAPL collection trenches cannot be placed within the habitat area because monitoring and maintenance activities associated with the trenches may cause damage to habitat area, limiting their adequacy. Institutional controls limiting activities that could cause trench damage would be required. The OMMP would require ongoing monitoring and maintenance/repair. Institutional controls will be put in place to restrict the habitat area to any access without permission from the EPA or designated person.

PRB (Funnel and Gate System). A properly designed funnel and gate system would be expected to be adequate and reliable in removing hydrocarbons, including benzene, naphthalene, and PAHs, from groundwater in the Shallow Aquifer approaching the shoreline. The volume of contaminated groundwater expected to be treated by the PRB is unknown. Treatment material may become saturated or become foul, and without frequent monitoring, the effectiveness of the PRB may be compromised. Treatability studies will be required to determine the effective treatment material specifications. The gate portion of the PRB would need to be placed in a location where treated groundwater would not become re-contaminated with DNAPL left in place. The PRB cannot be placed within the habitat area because monitoring and maintenance activities associated with the PRB may cause damage to habitat area. Institutional controls will be put in place to restrict the habitat area to any access without permission from the EPA or designated person. Long-term monitoring would be necessary to evaluate PRB performance and determine whether media replacement or other maintenance is needed. For the purpose of the FS, it is assumed that the PRB media would be replaced every 22 years over 100 years, although it is expected that the PRB would be required in perpetuity.

Sediment Caps. Same as Alternative 2.

ENR. Same as Alternative 2.

Institutional Controls. Because the vast majority of PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, institutional controls would be required and relied upon in perpetuity. For Alternative 3, there would also be more reliance on institutional controls to protect the additional remedy components (PRBs, DNAPL trenches, and solidified soils).

7.4.3.3 Alternative 3 Rating with Respect to this Criterion

Alternative 3 is rated “low” with respect to long-term effectiveness and permanence because the vast majority of PTW remains on-site untreated and the alternative relies heavily on capping and institutional controls to provide long-term protection.

7.4.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.4.4.1 Treatment Processes Used and Materials Treated

Alternative 3 incorporates additional technologies not associated with Alternative 2. They are: 1) collection trenches/PRB[9] to collect mobile DNAPL and to treat PAH-contaminated groundwater from the Shallow Aquifer as it migrates through the PRB; and 2) *in situ* solidification of the RR and MC-1 DNAPL Areas to treat PTWs that are a key source of groundwater contamination in the Deep Aquifer.

7.4.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 3, approximately 1,300 gallons of DNAPL from collection trenches is treated off-site (incinerated) and approximately 44,700 gallons of DNAPL are treated by *in situ* solidification.[10] The amount of contaminated groundwater treated by sorption in the PRB is unknown. The amount of DNAPL treated by sorption onto the RCM caps and reactive residual covers is unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.4.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 3 would reduce the volume and toxicity of upland DNAPL, through incineration, by approximately 1,300 gallons or 0.3 percent of the total DNAPL on-site.

Alternative 3 would reduce the mobility of upland DNAPL, through *in situ* solidification, by approximately 44,700 gallons or 10 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material remaining onsite would not be reduced.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes would be reduced by 26, 30, 16, and 1 percent, respectively. Mass flux for benzene, benzo(a)pyrene and naphthalene would be reduced by 57, 58, 56, and 3 percent, respectively.

The effectiveness of the RCM caps in Alternative 3 is the same as Alternative 2.

7.4.4.4 Degree to which Treatment is Irreversible

Treatment of DNAPL via *in situ* solidification would be expected to be essentially irreversible. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

Treatment of dissolved-phase contaminated groundwater migrating through the PRB containing GAC is expected to be irreversible by sorption onto the GAC. Treatment of DNAPL and dissolved constituents using RCM caps containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, for both technologies, the quantities of contaminants that would be sorbed are unknown.

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[9] Assumes likely use of granulated activated carbon (GAC) as the treatment material.

[10] The vast majority of contaminant mass at the Site is present as DNAPL or DNAPL-impacted soil or sediment (i.e., PTWs). Therefore, this consideration is primarily evaluated based on the amount of PTWs (as volume of DNAPL contained in those PTWs) that is treated.

7.4.4.5 Type and Quantity of Residuals Remaining after Treatment

RCM Sediment Capping. As in Alternative 2, a small amount of DNAPL would remain immobilized in the cap. Portions of the RCM cap may be periodically replaced and the DNAPL in those portions would likely be destroyed by incineration; refer to Section 7.3.4.5.

Upland DNAPL/Soil Solidification. DNAPL solidified in the soil matrix would remain on site, and mixed with the soil matrix, would comprise approximately 17,500 cy. The DNAPL within the solidified soil matrix that is bonded and the solidified matrix as a whole are not considered to be post-treatment residuals or untreated wastes; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL that has not been bonded to the matrix would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown.

Incineration of Collection Trench DNAPL. No residuals would remain on site.

PRB Treatment of Groundwater. Spent GAC used to treat groundwater would be transported off site for reactivation or disposal (8,800 cubic feet per installation, with an expected replacement frequency of 22 years).

7.4.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 3 does not satisfy the statutory preference for treatment as a primary component of the alternative because the majority of the contaminated materials remain on-site contained by the use of capping.

7.4.4.7 Alternative 3 Rating with Respect to this Criterion

Alternative 3 is rated "low" with respect to reduction of toxicity, mobility, or volume through treatment. DNAPL mobility in sediments would be reduced by the RCM cap. Treatment of PTWs in the RR and MC DNAPL Areas would moderately reduce the volume of contaminated groundwater, and the PRB would significantly reduce the mass flux of organic COCs to sediments. However, only a small portion of PTWs would be treated.

7.4.5 *Short-Term Effectiveness*

Alternative 3 has many of the same activities and protective measures as Alternative 2. Alternative 3 also has remedial construction activities that go beyond those in Alternative 2 and would require similar protective measures as a result of: 1) *in situ* solidification of 3,600 cy DNAPL-impacted soils and 2) construction of DNAPL collection trenches and the funnel and gate systems (PRB).

7.4.5.1 Protection of Community during Remedial Actions

For Alternative 3, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 3,200 cy of potentially contaminated sediment;

2) inhalation exposure to dust and vapors from excavation of 500 cy of DNAPL-impacted soil from construction of DNAPL collection trenches and the funnel and gate system;

3) inhalation exposure to dust and vapors from *in situ* solidification of 3,600 cy of DNAPL-impacted soil;

4) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 3,700 cy of potentially contaminated soils/sediment;

5) inhalation exposure of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and

6) inhalation exposure of the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

No unacceptable health risks to the community are expected even considering the slightly larger amounts of soil excavated and sediments containing hazardous materials dredged. This determination is based on the availability and use of BMPs and the amount of hazardous material handled on-site. BMPs and good housekeeping practices are the same as Alternative 2. Use of BMPs can mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet. *In situ* solidification is not expected to generate any appreciable amount of dust or air emissions. Approximately 3,700 cy of hazardous substances would be stockpiled on-site and then transported off-site for disposal.

Impacts to “quality of life” is assumed to be a concern of the neighboring community.

7.4.5.2 Protection of Workers during Remedial Actions

For Alternative 3, potential risks to site workers include the same exposure pathways as those associated with the neighboring community. However, additional exposures to workers can result from their close proximity to sources of exposure. These additional exposure pathways not only include inhalation but also dermal exposure pathways. On-site workers may be exposed to greater COC concentrations or frequency of dermal exposure which may not be applicable to the nearby community, e.g., dermal contact with contaminated soil. Potential exposure to hazardous substances to on-site workers may result from:

1) Inhalation and dermal exposure to potentially contaminated dust and vapors from excavation of 500 cy of DNAPL-impacted soil from construction of DNAPL collection trenches and the funnel and gate system;

2) Inhalation and dermal exposure to 3,600 cy of potentially contaminated soil, dust and vapors from *in situ* solidification of DNAPL-impacted soil;

3) Inhalation and dermal exposure to vapors and contaminated sediments during dredging of 3,200 cy of potentially contaminated sediment; and

4) Inhalation and dermal exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 3,700 cy of potentially contaminated soils/sediment.

No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. The addition of dermal exposure to workers, of greater COC concentrations or frequency, can be prevented by use of protective clothing and gear, adherence to Site-specific health and safety plans and construction quality assurance plans, plus BMPs. Protective practices put in place to protect the neighboring community also contribute to prevention of worker exposure to hazardous substances, such as use of BMPs to mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet.

7.4.5.3 Environmental Impacts

While there are some additional upland construction activities associated with Alternative 3 beyond those expected with Alternative 2, the impact to the environment is expected to be about the same as Alternative 2. Construction practices to prevent uplands activities from impacting the aquatic environment will be monitored and enforced by on-site EPA personnel. Dredging of potentially contaminated sediments is expected to increase by approximately 400 cy.

7.4.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed approximately 1.4 years from initiation of remedial construction (Figure 7-5). Similar with Alternative 2, the RAO for restoring groundwater to its highest beneficial use is not expected to be achieved within 100 years. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs are also not expected to be met immediately, although caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.4.5.5 Alternative 3 Rating with Respect to this Criterion

Alternative 3 is rated “high” with respect to short-term effectiveness. There is a little increase in the amount of potentially contaminated sediments to be dredged and handled for off-site disposal and a modest increase in the amount of DNAPL-impacted soils. No unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. Impacts to the environment are the same as Alternative 2.

7.4.6 *Implementability*

7.4.6.1 Technical Feasibility

Alternative 3 incorporates three additional construction elements beyond the three used in Alternative 2. They are: 1) construction and maintenance of DNAPL collection trenches; 2) construction and maintenance of PRB systems; and 3) implementation of *in-situ* solidification. These six construction elements use proven technologies, and their construction is technically feasible. While PRBs are considered a proven technology for metals, there is less history regarding the effectiveness of using GAC in PRBs for organic COCs.

Alternative 3 would likely be more complex to implement because there are three additional remedial technologies that are incorporated beyond the three in Alternative 2, for a total of six construction elements. Alternative 3 would provide an additional challenge to project sequencing and contractor coordination because of the increased number of construction elements. Additionally, there may be some technical feasibility issues regarding the success of replacing the reactive media in the PRB once it becomes saturated. While both PRB and solidification require bench and pilot testing, this is not considered to be an implementability concern. Alternative 3 incorporates three remedial technologies (RCM caps, PRBs, and collection trenches) that require ongoing maintenance and problematic replacement or repair, in perpetuity.

7.4.6.2 Administrative Feasibility

Alternative 3 may also provide more administrative feasibility issues than Alternative 2 because of multiple and different types of expertise and construction contracts to be developed and issued for bids and reviewed and negotiated.

7.4.6.3 Availability of Services and Materials

Same as Alternative 2.

7.4.6.4 Alternative 3 Rating with Respect to this Criterion

Implementability for Alternative 3 is “low” because of the use of multiple passive and active remedial technologies to be coordinated during remedial action and concerns regarding the feasibility and effectiveness of replacing and repairing RCM caps and reactive media in PRBs, and maintenance of DNAPL collection trenches. All of these technologies will require maintenance and monitoring in perpetuity.

7.4.7 *Cost*

The estimated present worth cost of Alternative 3 is $31 million, including a projected $22 million for capital construction and $9.2 million (present worth) for OM&M.

7.5 Detailed Evaluation of Alternative 4

Alternative 4 includes the same remedies as Alternative 3, but instead of treating deep upland PTWs to reduce the groundwater contaminant plume volume, Alternative 4 removes potentially mobile PTWs in the QP-U and QP-S DNAPL Areas and selected TD DNAPL Areas. Removal of mobile PTWs in the QP DNAPL Areas eliminates the potential for PTWs to migrate into and within lake sediments. The purpose of removing PTW in selected TD DNAPL Area (DA-1 and DA-2) is to address Washington Department of Natural Resource concerns regarding the placement of sediment caps in State-Owned Aquatic Lands. Other PTW in lake sediments will capped as in Alternative 3. Refer to Section 6.3.4 for a detailed description.

7.5.1 *Overall Protection of Human Health and the Environment*

Alternative 4 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.5.1.1) and the environment (Section 7.5.1.2) as follows:

7.5.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 4. Approximately 10 percent of the upland PTW that causes the groundwater contamination is removed in this alternative. Treatment of shallow groundwater leaving the uplands and entering the lake using a PRB would restore an unknown amount of groundwater. Overall, the groundwater plume would be reduced by 15 percent as compared to Alternative 1 (No Action). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternatives 2 and 3.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 3, except that QP-S sediments and selected T-Dock sediments would be dredged rather than capped (addressing approximately 88 percent of the aquatic PTWs). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternatives 2 and 3.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 3, except QP-S sediments would be dredged instead of capped.

- **HH4: Reduce Risks to Recreational Beach Users From Exposure to Surface Water to Acceptable Levels.** Same as Alternative 3, except QP-S sediments would be dredged instead of capped.

- **HH5: Reduce Risk to Future Residents from Exposure to Indoor Vapors to Acceptable Levels.** Same as Alternative 2, except vapor intrusion would be reduced by a nominal amount due to the excavation of PTWs in the QP-U DNAPL Area. Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs would also be reduced and controlled by a combination of excavation, soil caps, and institutional controls. Excavation of the QP-U DNAPL Area would not reduce vapors sufficiently to reduce or change institutional or engineering controls for vapor intrusion as identified in Alternative 2.

- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Same as Alternative 3, except that an estimated 15,600 cy of soil from the QP-U DNAPL Area would be excavated along with construction of the DNAPL collection trenches and the funnel and gate system, as opposed to an estimated 17,500 cy of soil being treated with in situ stabilization and approximately 2,900 cy of soil being excavated for the trenches and PRB.

7.5.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 3, except that QP-S sediments and selected T-Dock sediments would be dredged rather than capped (addressing approximately 88 percent of the aquatic PTWs).

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 3.
- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 3, except that QP-S sediments and selected T-Dock sediments would be dredged rather than capped.

7.5.1.3 Alternative 4 Rating with Respect to this Criterion

Alternative 3 does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated "high" for Short-Term Effectiveness (Section 7.5.5) and rated "moderate" for Long-Term Effectiveness and Permanence (Section 7.5.3). However, the RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor would the alternative be a candidate for a TI waiver (Section 7.5.2). Protectiveness would be addressed via institutional controls and monitoring.

7.5.2 *Compliance with ARARs*

Alternative 4 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. The extent to which MCLs would be achieved in this alternative is discussed below.

7.5.2.1 Compliance with the MCL ARAR

For Alternative 4, groundwater volume exceeding MCLs is predicted to decrease by 20 percent for benzene, 6 percent for benzo(a)pyrene and 2 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 4, the groundwater volume exceeding MCLs in the aggregate was predicted, to decrease by 19 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.5.2.2 Technical Impracticability Waiver

Same as Alternative 3. It is assumed that Alternative 4 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTWs are readily accessible and removal or treatment is feasible with currently available engineering technology.

7.5.2.3 Alternative 4 Rating with Respect to this Criterion

Alternative 4 does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.5.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 4 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.5.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

Approximately 78 percent (by volume) of PTW is left in place as untreated waste; therefore DNAPL-impacted soils and sediment remain in place and untreated at 27,700 and 32,400 cy, respectively. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBC are reduced (benzene 20 percent; naphthalene 12 percent; benzo[a]pyrene 6 percent; and arsenic 2 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.5.3.2 Adequacy and Reliability of Controls

Controls in Alternative 4 include an upland cap, DNAPL collection trenches, a PRB (funnel and gate system), sediment caps (engineered sand cap and RCM sediment cap), reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternative 3.

RCM Cap. Same as Alternative 3.

DNAPL Collection Trenches. Same as Alternative 3.

PRB (Funnel and Gate System). Same as Alternative 3.

Sediment Caps. Same as Alternative 3, except for areas dredged in Alternative 4.

Reactive Residuals Cover. Similar to an RCM cap, a reactive residuals cover would be adequate and reliable in preventing direct contact with contaminated sediments, providing a clean bioturbation layer and in protecting surface water resources. Institutional controls will restrict/prohibit activities that may compromise the integrity of the covers. The OMMP will specify long-term monitoring required to evaluate whether the covers are functioning as required, and the remedial maintenance actions and repair actions that are taken if reactive sediments covers fail to perform as required.

Reactive residuals covers may lose their effectiveness when the amended/reactive material becomes saturated or damaged. Therefore, for continued effectiveness, such covers would need to be designed to include a mechanism to allow for replacement of reactive media as needed. Long-term monitoring would be necessary to determine if and when replacement or additional reactive materials are needed. Mixing reactive material with capping media is an evolving technology and is expected to be used successfully in the future. The sediment covers would be required to remain in place and effective in perpetuity.

ENR. Same as Alternatives 2 and 3.

Institutional Controls. Same as Alternative 3. Because the vast majority of PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, institutional controls would be required and relied upon in perpetuity.

7.5.3.3 Alternative 4 Rating with Respect to this Criterion

Alternative 4 is rated "low" with respect to long-term effectiveness and permanence because removal of PTWs in the QP DNAPL Areas eliminates the potential for PTWs to migrate into and within lake sediments. However, the vast majority of PTW remains on-site untreated and the alternative still relies heavily on capping and institutional controls to provide long-term protection.

7.5.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.5.4.1 Treatment Processes Used and Materials Treated

Treatment technologies used in Alternative 4 include 1) RCM caps to sorb DNAPL in the event that DNAPL is disturbed and migrates upward to the cap, 2) a PRB to treat contaminated groundwater moving toward the lake, 3) and reactive residuals covers over dredged areas to sorb any remaining PTW that may be left behind.

7.5.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 4, approximately 1,300 gallons of DNAPL from collection trenches is treated (incinerated). The amount of contaminated groundwater treated by sorption in the PRB is unknown. The amount of DNAPL treated by sorption onto the RCM caps and reactive residual covers is also unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.5.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 4 would reduce the volume and toxicity of upland DNAPL, through incineration, by approximately 1,300 gallons or 0.3 percent of the total DNAPL on-site.

The aquatic RCM caps and residual covers would be expected to be effective at preventing DNAPL migration from underlying sediments into the surface waters of Lake Washington. The RCM caps should also be highly effective in treating and reducing the volume of dissolved-phase contaminants flowing into the lake; however, the volume of dissolved-phase contaminants treated by the caps and covers is unknown.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 40, 20, 10, and less than zero percent, respectively. The mass flux reduction (due to the PRB) for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 74, 61, 83, and less than zero percent, respectively.

7.5.4.4 Degree to which Treatment is Irreversible

Treatment of DNAPL from collection trenches that is incinerated is irreversible. Treatment of dissolved-phase contaminated groundwater migrating through the PRB containing GAC is expected to be irreversible by sorption onto the GAC. Treatment of DNAPL and dissolved constituents using RCM caps and residual covers containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, for both technologies, the quantities that would be sorbed are unknown.

7.5.4.5 Type and Quantity of Residuals Remaining after Treatment

The type and quantity of residuals remaining after treatment would be the same as Alternative 3, except there would be no solidified materials onsite.

7.5.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 4 does not satisfy the statutory preference for treatment as a primary component of the alternative because the majority of the alternative is containment.

7.5.4.7 Alternative 4 Rating with Respect to this Criterion

Alternative 4 is rated "low" with respect to reduction of toxicity, mobility, or volume through treatment. Mobility of DNAPL remaining in sediments would be reduced by reactive sediment caps and dredging residual covers. The PRB would slightly reduce contaminated groundwater volume and significantly reduce contaminant mass flux of organic COCs to sediments. However, only a very small portion of PTWs would be treated.

7.5.5 *Short-Term Effectiveness*

Alternative 4 has some of the same activities as Alternative 3, but also includes remedial construction activities that go beyond or are different than Alternative 3. Alternative 4 dredges and excavates some of the DNAPL-impacted sediment and soil, respectively instead of capping all DNAPL-impacted contaminated soils and sediments.

7.5.5.1 Protection of Community during Remedial Actions

For Alternative 4, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 25,900 cy of potentially contaminated sediment;
2) inhalation exposure to dust and vapors from excavation of 2,800 cy of DNAPL-impacted soil;
3) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 28,700 cy of potentially contaminated soils/sediment;
4) inhalation exposure to dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and
5) inhalation exposure to the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

No unacceptable health risks to the community are expected even considering the larger amounts of soil excavated and sediments containing hazardous materials dredged. This determination is based on the availability and use of BMPs and the amount of hazardous material handled on-site. BMPs and good housekeeping practices are the same as Alternative 3. Use of BMPs can mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet. Even though significantly larger volumes of contaminated sediments are dredged compared to previous alternatives, the frequency of failure of BMPs and protective measures to mitigate exposure is not expected to increase compared to Alternative 3. Failures that may cause increased exposure are the same as Alternative 3 and by their nature can quickly be determined and repaired. Special repair equipment or machine parts are not a factor for Alternative 4.

Impacts to "quality of life" is assumed to be a concern of the neighboring community.

7.5.5.2 Protection of Workers during Remedial Actions

For Alternative 4, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and/or contaminated sediments from during dredging of 25,900 cy of potentially contaminated sediment;
2) inhalation and dermal exposure to dust and vapors from excavation of 2,800 cy of DNAPL-impacted soil;
3) inhalation and dermal exposure to dust or air emissions may also occur from handling and stockpiles for transport off-site, by truck, of 28,700 cy of potentially contaminated soils/sediment;
4) inhalation exposure to vapors from during dredging of 25,900 cy of potentially contaminated sediment;
5) inhalation and dermal exposure to dust and vapors from excavation of 2,800 cy of DNAPL-impacted soil; and
6) inhalation and dermal exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 28,700 cy of potentially contaminated soils/sediment.

No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. The addition of dermal exposure to workers, of greater COC concentrations or frequency, can be prevented by use of protective clothing and gear, adherence to Site-specific health and safety plans and construction quality assurance plans, plus BMPs. Protective practices put in place to protect the neighboring community also contribute to prevention of worker exposure to hazardous substances, such as use of BMPs to mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet.

7.5.5.3 Environmental Impacts

Environmental impacts associated with construction of the DNAPL collection trenches and the funnel and gate systems would be expected to be minimal, assuming implementation of adequate erosion and sedimentation control measures.

Disturbance of PTW soils along the shoreline and PTW sediments would have the potential to mobilize DNAPL and result in significant short-term environmental impacts to the aquatic environment if not adequately controlled. Potential short-term impacts of sediment dredging and capping are depicted on Figure 7-4, and are summarized below.

- **Excavation/Dredging.** As discussed in Appendix C, Section C5.3.2, studies have concluded that a small percentage of the solids excavated or dredged during the last dredge production cut may accumulate as a post-dredge residual layer. The environmental hydraulic dredging proposed for the aquatic offshore DNAPL areas would provide a high level of control and residual solids would be expected to be minimal. These dredges have greater control of resuspension than conventional hydraulic or mechanical dredges. In addition, short-term impacts would be reduced by containing the aquatic dredge areas within oil-sorbent booms and/or silt curtains (if necessary). The deeper nearshore sediments would be removed using a mechanical dredge with an environmental bucket. A temporary sheet pile enclosure would be installed around the nearshore removal area to isolate the dredging activities from the lake as well as support removal of sediments at depth. Sealed sheet pile walls provide the greatest isolation of contaminants from the water body during dredging; however, there is also the potential for release of dissolved contaminants, DNAPL, and suspended solids during sheet pile installation. Additional characterization during remedial design may be needed to reduce the potential for installing sheet-pile in areas with DNAPL. In areas where dredging occurs, the fish habitat and benthic community would be significantly altered and/or eliminated in the short term; however, acceptable concentrations are assumed to be managed through application of residual covers. Assuming concentrations are acceptable, recolonization would be expected within several months (McCabe et al. 1998).
- **Capping and ENR.** As for Alternatives 2 and 3, capping and ENR will cause short-term impacts to the water column due to the material being placed and also due to coming in contact with contaminated surface sediment and possibly causing resuspension. In areas where capping or ENR occurs, the benthic community would be significantly altered and/or eliminated in the short term. Assuming concentrations are acceptable, recolonization would be expected within several months (McCabe et al. 1998).

Because Alternative 4 would include a moderate amount of PTW shoreline soil and PTW sediment removal, it would be expected to have a moderate overall potential for environmental impacts.

7.5.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed roughly 2 to 3 years from initiation of remedial construction; however, not all RAOs (refer to Section 7.5.1) would be achieved at the end of the construction period (Figure 7-5). The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would not be met within 100 years. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a "clean" sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.5.5.5 Alternative 4 Rating with Respect to this Criterion

Alternative 4 is rated "moderate" with respect to short-term effectiveness because it would involve moderate construction activities, including significant sediment dredging. Short-term risks to the community are expected to be managed with proper planning, communication, and BMPs. Negative short-term environmental impacts are expected to the benthic community but recovery is expected.

7.5.6 *Implementability*

7.5.6.1 Technical Feasibility

Alternative 4 incorporates two additional construction elements beyond the six used in Alternative 3, for a total of eight construction elements. The additional construction elements are: 1) removal of a limited amount of PTW soil by a combination of upland-based excavation equipment and mechanical dredging, along the shoreline; and 2) removal of a limited amount of PTW sediment by a combination of mechanical and hydraulic dredging. These additional remedial technologies are well understood technologies, have been widely used over a number of years and are considered to be technically feasible for the Quendall site. These eight construction elements use proven technologies, and their construction is technically feasible.

Excavation and dredging DNAPL-impacted soil and sediments can be operationally challenging not because of the technology itself but because of the DNAPL-impacted media being removed. Dredging and excavation pose technical challenges beyond those associated with some other remedial technologies such as installation of engineered caps. However, dredging and excavation can be generally successful in eliminating residuals, to the extent possible, when using expert operators, proper equipment and plans, including BMPs and isolation barriers to the maximum extent. Generation of residuals does not make dredging or excavation technically infeasibility. Residuals can be mitigated through the use of residual covers over dredged surfaces.

Of the two methods of dredging proposed in Alternative 4, environmental hydraulic dredging is used on a smaller scale and is simpler to implement than mechanical dredging. Environmental hydraulic dredging transports the sediment to the processing site within a pipeline and dewaters the sediment in a contained vacuum box. Mechanical dredging transports the sediment in a barge and requires rehandling and additional space for transloading and dewatering on site. The mechanical dredging of nearshore sediment would also require sheet pile procurement, shipping, staging, installation, and removal, making it more challenging to effectively implement.

However, Alternative 4 only uses RCMs caps in 2.0 acres compared to 4.9 and 5.7 acres as in Alternatives 2 and 3, respectively. RCMs caps, as noted above, pose more uncertainties and technical challenges in placing, maintenance, repair and monitoring than do excavation and dredging. As in Alternative 3, Alternative 4 also poses challenges to project sequencing and contractor coordination because of the increased number of construction elements, such as upland excavation, two separate sediment-dredging methods and the need to provide access for mobilization/demobilization and staging. As in Alternative 3, Alternative 4 incorporates 3 remedial technologies, RCM caps, PRBs, and DNAPL collection trenches that require ongoing maintenance and problematic replacement or repair, in perpetuity.

7.5.6.2 Administrative Feasibility

Same as Alternative 3.

7.5.6.3 Availability of Services and Materials

Same as Alternative 3.

7.5.6.4 Alternative 4 Rating with Respect to this Criterion

Implementability for Alternative 4 is “moderate”. Even though the number of construction elements is greater by two than in Alternative 3, Alternative 4 reduces the acreage of sediment covered by a RCM cap by instead dredging that area, thus reducing the extent of ongoing maintenance and repair or replacement of RCM caps in perpetuity.

7.5.7 *Cost*

The estimated present worth cost of Alternative 4 is $44 million, including a projected $40 million for capital construction and $4.8 million (present worth) for OM&M.

7.6 Detailed Evaluation of Alternative 4a

Alternative 4a includes (1) *in situ* solidification of PTWs in the RR and MC-1 DNAPL Areas to address the deepest occurrences of DNAPL, which are a key source of contamination to the Deep Aquifer, (2) *in situ* solidification of PTW in the QP-U DNAPL Area to address large quantities of DNAPL that could potentially migrate into adjacent Lake Washington, (3) a DNAPL collection trench system to remove mobile PTWs from the shallow subsurface to further reduce the potential migration of DNAPL from the uplands to the lake sediments, (4) a PRB to treat contaminated groundwater in the upland Shallow Aquifer as it migrates west toward the shoreline, and (5) dredging of selected TD DNAPL Areas (DA-1, DA-2 and DA-6) to address DNAPL in shallow sediments. The remaining aquatic areas are addressed via the same RCM caps, engineered sand caps, and ENR as Alternatives 2 and 3. Refer to Section 6.3.5 for a detailed description.

7.6.1 *Overall Protection of Human Health and the Environment*

Alternative 4a would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.6.1.1) and the environment (Section 7.6.1.2) as follows:

7.6.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 4a. Approximately 21 percent of the upland PTW that causes the groundwater contamination is addressed in this alternative. Treatment of shallow groundwater leaving the uplands and entering the lake using a PRB would restore an unknown amount of groundwater. Overall, the groundwater plume would be reduced by approximately 30 percent as compared to Alternative 1 (No Action). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternatives 2, 3, and 4.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 4, except the QP-S Area is capped with an RCM cap rather than dredged.
- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 4, except the QP-S Area is capped with an RCM cap rather than dredged.
- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 4, except the QP-S Area is capped with an RCM cap rather than dredged.
- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels**: Same as Alternative 3, except vapor intrusion would be reduced by a nominal amount due to additional *in situ* solidification of the PTWs in the QP-U DNAPL Areas. Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs throughout the Site would also be reduced and controlled to acceptable levels by soil caps and institutional controls. Treatment of the MC-1 DNAPL Area, which underlies the potential future location of mixed use buildings, would not reduce exposure to vapors sufficiently to reduce or change institutional controls, engineering controls or capping requirements for vapor intrusion as identified in Alternative 2.[11]
- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Same as Alternative 3, except the QP-U DNAPL area will also be treated. The treated areas may not require a cap. Human health risk from direct contact or incidental ingestion of COCs in soil would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. A total of approximately 31,800 cy of soil would be treated with *in situ* solidification and approximately 2,900 cy of soil would be excavated during construction of the DNAPL collection trenches and the funnel and gate systems. It is assume that excavated PTWs and associated contaminated soil will be disposed at a RCRA Subtitle C Landfill.

[11] The QP-U DNAPL Area is located wholly within the habitat area, where no future building would be allowed.

7.6.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 4, except the QP-S DNAPL Area is capped with an RCM cap rather than dredged.
- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 4, except the QP-S DNAPL Area is capped with an RCM cap rather than dredged.
- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 4, except the QP-S DNAPL Area is capped with an RCM cap rather than dredged.

7.6.1.3 Alternative 4a Rating with Respect to this Criterion

Alternative 4a does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated "high" for Short-Term Effectiveness (Section 7.6.5) and rated "low" for Long-Term Effectiveness and Permanence (Section 7.6.3). However, the RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor would the alternative be a candidate for a TI waiver (Section 7.6.2). Protectiveness would be addressed via institutional controls and monitoring.

7.6.2 *Compliance with ARARs*

Alternative 4a would comply with the chemical-specific, action-specific, and location-specific ARARs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. The extent to which MCLs would be achieved in this alternative is discussed below.

7.6.2.1 Compliance with the MCL ARAR

For Alternative 4a, groundwater volume exceeding MCLs is predicted to decrease by 37 percent for benzene, 13 percent for benzo(a)pyrene and 5 percent for arsenic, relative to the No Action alternative, 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 4a, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by 35 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.6.2.2 Technical Impracticability Waiver

It is assumed that Alternative 4a would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTWs are readily accessible and removal or treatment is feasible with currently available engineering technology.

7.6.2.3 Alternative 4a Rating with Respect to this Criterion

Alternative 4a does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.6.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 4a is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.6.3.1 Magnitude of Residual Risks

In this subsection, the magnitude of residual risks associated with untreated waste/ treatment residuals left on-site after remediation is presented in terms of the degree to which PTW sources are remediated and the percent the plume is reduced.

Approximately 74 percent (by volume) of the PTW is left in place as untreated waste; therefore, DNAPL-impacted soils and sediment remain in place at 24,100 and 43,400 cy, respectively. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBCs are reduced (benzene at 37 percent, naphthalene at 26 percent, benzo[a]pyrene at 13 percent, and arsenic at 5 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.6.3.2 Adequacy and Reliability of Controls

Controls in Alternative 4a include an upland cap, DNAPL collection trenches, a PRB (funnel and gate system), sediment caps (engineered sand cap and RCM caps), ENR, institutional controls, and monitoring.

Adequacy and reliability of controls can be assessed by examining the complexity and efficacy of requirements for long-term operation, maintenance and monitoring of the alternative. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternatives 2, 3, and 4.

DNAPL Collection Trenches. Same as Alternatives 3 and 4.

PRB (Funnel and Gate System). Same as Alternatives 3 and 4.

Sediment Caps. Same as Alternative 4, except selected TD DNAPL Areas are dredged instead of the QP-S DNAPL Area.

ENR. Same as Alternatives 2, 3, and 4.

Institutional Controls. Same as Alternative 3. Because the vast majority of PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, institutional controls would be required and relied upon in perpetuity. However, for Alternative 4a, there are more remedy components than Alternative 3 (sediment dredging).

7.6.3.3 Alternative 4a Rating with Respect to this Criterion

Alternative 4a is rated “low” with respect to long-term effectiveness and permanence because the vast majority of PTW remains on-site untreated and the alternative relies heavily on capping and institutional controls to provide long-term protection.

7.6.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.6.4.1 Treatment Processes Used and Materials Treated

Treatment technologies used in Alternative 4a include: 1) *in situ* solidification of the RR and MC-1 DNAPL Areas to treat PTWs that are a key source of groundwater contamination in the Deep Aquifer, 2) *in situ* solidification of the QP-U DNAPL Area to treat PTWs that may potentially migrate into adjacent Lake Washington, 3) RCM caps to sorb DNAPL in the event that DNAPL is disturbed and migrates upward to the cap, 4) a PRB to treat contaminated groundwater moving toward the lake, 5) and reactive residuals covers over selected TD DNAPL Area dredged areas to sorb any remaining PTW that may be left behind.

7.6.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 4a, approximately 1,300 gallons of DNAPL from collection trenches is treated off-site (incinerated) and approximately 73,000 gallons of DNAPL are treated by *in situ* solidification.[12] The amount of contaminated groundwater treated by sorption in the PRB is unknown. The amount of DNAPL treated by sorption onto the RCM caps and reactive residual covers is also unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.6.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 4a would reduce the volume and toxicity of upland DNAPL, through incineration, by approximately 1,300 gallons or 0.3 percent of the total DNAPL on-site.

Alternative 4a would reduce the mobility of upland DNAPL, through *in situ* solidification, by approximately 73,000 gallons or 16 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material remaining onsite would not be reduced. The effectiveness of the RCM caps and residual covers in Alternative 5 is the same as Alternative 4.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes would be reduced by 26, 30, 16, and 1 percent, respectively. Mass flux for benzene, benzo(a)pyrene and naphthalene would be reduced by 80, 81, 89, and 5 percent, respectively.[13]

7.6.4.4 Degree to which Treatment is Irreversible

The vast majority of DNAPL in *in situ* solidification is expected to be treated and solidification treatment would be expected to be essentially irreversible. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

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[12] The vast majority of contaminant mass at the Site is present as DNAPL or DNAPL-impacted soil or sediment (i.e., PTWs). Therefore, this consideration is primarily evaluated based on the amount of PTWs (as volume of DNAPL contained in those PTWs) that is treated.

[13] Mass flux for Alternative 4a was not modeled directly; however, its performance is expected to be similar to Alternative 5 because it contains similar remedial components in the uplands near the shoreline.

Like Alternatives 3 and 4, treatment of dissolved-phase contaminated groundwater migrating through the PRB is expected to be irreversible, as is treatment of DNAPL using RCM caps. At present, for both technologies, the quantities of contaminants that would be sorbed are unknown.

7.6.4.5 Type and Quantity of Residuals Remaining after Treatment

The type and quantity of residuals remaining after treatment would be the same as Alternative 3, except the DNAPL in the stabilized matrix would comprise approximately 31,800 cy.

7.6.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 4 does not satisfy the statutory preference for treatment as a primary component of the alternative because the majority of the alternative is containment.

7.6.4.7 Alternative 4a Rating with Respect to this Criterion

Alternative 4a is rated "low" with respect to reduction of toxicity, mobility, or volume through treatment. DNAPL mobility in sediments would be reduced by the RCM cap. Treatment of PTWs in the RR, MC, and QP-U DNAPL Areas would moderately reduce the volume of contaminated groundwater, and the PRB would significantly reduce the mass flux of organic COCs to sediments. However, only a small portion of PTWs would be treated.

7.6.5 *Short-Term Effectiveness*

7.6.5.1 Protection of Community during Remedial Actions

For Alternative 4a, potential exposure to hazardous substances to the neighboring community may result from:

6) inhalation exposure to vapors from during dredging of 25,900 cy of potentially contaminated sediment;
7) inhalation exposure to dust and vapors from excavation of 500 cy of DNAPL-impacted soil;
8) inhalation exposure to dust and vapors from *in situ* solidification of 5900 cy of DNAPL-impacted soil;
9) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 15,400 cy of potentially contaminated soils/sediment;
10) inhalation exposure to dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and
11) inhalation exposure to the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

No unacceptable health risks to the community are expected because smaller amounts of soil excavated and sediments containing hazardous materials dredged than in previous alternatives. Even though more DNAPL-impacted soil is solidified than in Alternative 3, solidification is expected not to generate as much dust as in Alternative 4 where DNAPL-impacted soil is excavated, a significantly larger volume of contaminated sediments are dredged than in Alternative 4a and then transported off-site for disposal. This determination is based on the availability and use of BMPs and the amount of hazardous material handled on-site. BMPs and good housekeeping practices are the same as Alternatives 3 and 4. Use of BMPs can mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet. The frequency of failure of BMPs and protective measures to mitigate exposure is not expected to increase compared to Alternative 3. Failures that may cause increased exposure are the same as Alternative 3 and by their nature can quickly be determined and repaired. Special repair equipment or machine parts are not a factor for Alternative 4a.

Impacts to “quality of life” is assumed to be a concern of the neighboring community.

7.6.5.2 Protection of Workers during Remedial Actions

For Alternative 4a, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and/or contaminated sediments from during dredging of 25,900 cy of potentially contaminated sediment;
2) inhalation and dermal exposure to dust and vapors from excavation of 500 cy of DNAPL-impacted soil;
3) inhalation and dermal exposure to dust or air emissions may also occur from handling and stockpiles for transport off-site, by truck, of 15,400 cy of potentially contaminated soils/sediment;
4) inhalation exposure to vapors from during dredging of 14,900 cy of potentially contaminated sediment; and

No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. The addition of dermal exposure to workers, of greater COC concentrations or frequency, can be prevented by use of protective clothing and gear, adherence to Site-specific health and safety plans and construction quality assurance plans, plus BMPs. Protective practices put in place to protect the neighboring community also contribute to prevention of worker exposure to hazardous substances, such as use of BMPs to mitigate inhalation exposure by active management of potential emissions by covering stockpiles, truck loads and/or keeping areas prone to generating emissions wet.

7.6.5.3 Environmental Impacts

Environmental impacts associated with construction of the DNAPL collection trenches and the funnel and gate systems would be expected to be minimal, assuming implementation of adequate erosion and sedimentation control measures.

While there are some additional upland construction activities associated with Alternative 4a beyond those expected with Alternative 3, the impact to the environment is expected to be about the same as Alternative 3. Construction practices to prevent uplands activities from impacting the aquatic environment will be monitored and enforced by on-site EPA personnel. Dredging of potentially contaminated sediments is expected to increase by approximately 11,700 cy.

7.6.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed roughly 2 to 3 years from initiation of remedial construction; however, not all RAOs (refer to Section 7.5.1) would be achieved at the end of the construction period (Figure 7-5). The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would not be met within 100 years. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.6.5.5 Alternative 4a Rating with Respect to this Criterion

Alternative 4a is rated “moderate” with respect to short-term effectiveness because it would involve moderate construction activities, including increased dredging compared with Alternatives 2 and 3 but much less than Alternative 4.

7.6.6 *Implementability*

7.6.6.1 Technical Feasibility

The technical feasibility of *in situ* solidification of PTW soils, DNAPL trenches, the funnel and gate systems, and upland capping are the same as Alternative 3. The technical feasibility of the aquatic remedies is the same as Alternative 4 for hydraulic dredging, RCM caps, and ENR.

7.6.6.2 Administrative Feasibility

The administrative feasibility of *in situ* solidification of PTW soils, DNAPL trenches, the funnel and gate systems, and upland capping are the same as Alternative 3. The administrative feasibility of the aquatic remedies is the same as Alternative 4 for hydraulic dredging, RCM caps, and ENR.

7.6.6.3 Availability of Services and Materials

Necessary engineering and construction services are readily available, with multiple experienced contractors procurable through competitive bidding. Sufficient sand and gravel mine production capacity exists within 20 miles of the Site to supply the required capping material. Sufficient regional landfill capacity exists to receive contaminated sediments generated in this alternative.

7.6.6.4 Alternative 4a Rating with Respect to this Criterion

Alternative 4a is rated "moderate" with respect to implementability because, while the alternative rates "high" for administrative feasibility and availability of services and materials, technical feasibility is rated "moderate" because there is little experience with installation of RCM caps and especially with the replacement and repair of RCM caps.

7.6.7 *Cost*

The estimated present worth cost of Alternative 4a is $34 million, including a projected $29 million for capital construction and $4.9 million (present worth) for OM&M.

7.7 Detailed Evaluation of Alternative 5

Alternative 5 incorporates the same upland remedial technologies as Alternative 3[14] to treat groundwater and restore a portion of the Deep Aquifer, and the same aquatic remedial technologies as Alternative 4 to remove PTWs in shallow sediments. In addition, this alternative expands the area of upland soil solidification to also include the QP-U DNAPL Area, to target potentially mobile DNAPL located adjacent to Lake Washington (the same area targeted for excavation in Alternative 4), and areas containing at least 4-feet cumulative thickness of DNAPL-impacted soil, to efficiently treat the greatest volume of accessible PTWs. Refer to Section 6.3.5 for a detailed description.

7.7.1 *Overall Protection of Human Health and the Environment*

Alternative 5 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.6.1.1) and the environment (Section 7.6.1.2) as follows:

7.7.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 5. While 57 percent of the upland PTW that causes the groundwater contamination is treated or removed in this alternative, enough remains to continue as a source of groundwater contamination for hundreds of years. Treatment of shallow groundwater leaving the uplands and entering the lake using a PRB would restore an unknown amount of groundwater. Overall, the groundwater plume would be reduced by 31 percent as compared to Alternative 1 (No Action). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternatives 2, 3, and 4.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 4.

[14] Alternative 5 includes the upland components of Alternative 3 except without DNAPL collection trenches. Areas targeted for DNAPL collection trenches in Alternative 3 are targeted for solidification in Alternative 5.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 4.

- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 4.

- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Same as Alternative 3, except vapor intrusion concerns would be additionally reduced by *in situ* solidification treatment of the PTW with cumulative depths of 4 feet or more. Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs throughout the Site would also be reduced and controlled to acceptable levels by soil caps and institutional controls. Treatment of DNAPL at cumulative depths of 4 feet or more may not reduce exposure to vapors sufficiently to reduce or change institutional controls, engineering controls or capping requirements for vapor intrusion as identified in Alternative 3.

- **HH6: Reduce Risk to Soil to Acceptable Levels.** Same as Alternative 3, except a larger area of the uplands will be treated or excavated. These areas would be noted on the appropriate institutional controls and may not require a cap. Otherwise, human health risk from direct contact or incidental ingestion of COCs in soil would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. A total of approximately 78,900 cy of soil would be treated with *in situ* solidification and approximately 2,100 cy of soil would be excavated during construction of the DNAPL collection trenches and the funnel and gate systems.

7.7.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 4.

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 4.

- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 4.

7.7.1.3 Alternative 5 Rating with Respect to this Criterion

Alternative 5 does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated “moderate” for Short-Term Effectiveness (Section 7.7.5) and for Long-Term Effectiveness and Permanence (Section 7.7.3). However, the RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor is it a candidate for a TI waiver (Section 7.7.2). Protectiveness would be therefore be addressed via institutional controls and monitoring.

7.7.2 *Compliance with ARARs*

Alternative 5 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. Approximately 62 percent of the PTW that causes the groundwater contamination is removed or treated in this alternative. The extent to which MCLs would be achieved in this alternative is discussed below.

7.7.2.1 Compliance with the MCL ARAR

For Alternative 5, the groundwater volume exceeding MCLs is predicted to decrease by 40 percent for benzene, 31 percent for benzo[a]pyrene and 8 percent for arsenic relative to the No Action alternative one hundred years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 5, the groundwater volume exceeding MCLs in the aggregate plume was predicted to decrease by roughly 35 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.7.2.2 Technical Impracticability Waiver

It is assumed that Alternative 5 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTWs are readily accessible and removal or treatment is feasible with currently available engineering technology.

7.7.2.3 Alternative 5 Rating with Respect to this Criterion

Alternative 5 does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.7.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 5 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.7.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

Approximately 38 percent (by volume) of PTW is left in place as untreated waste; therefore DNAPL-impacted soils and sediment remain in place and untreated at 13,100 and 32,400 cy, respectively. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBCs are reduced (benzene at 40 percent, naphthalene at 29 percent, benzo[a]pyrene at 31 percent, and arsenic at 8 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.7.3.2 Adequacy and Reliability of Controls

Controls in Alternative 5 include an upland cap, a PRB (funnel and gate system), sediment caps (engineered sand cap and reactive sediment cap), reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternatives 2, 3, and 4.

PRB (Funnel and Gate System). Same as Alternatives 3 and 4.

Sediment Caps. Same as Alternative 4.

Reactive Residuals Cover. Same as Alternative 4.

ENR. Same as Alternatives 2, 3, and 4.

Institutional Controls. Same as Alternatives 3 and 4a. Because most of the PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, institutional controls would be required and relied upon in perpetuity.

7.7.3.3 Alternative 5 Rating with Respect to this Criterion

Alternative 5 is rated "moderate" with respect to long-term effectiveness and permanence because, while it treats or removes more than half of the PTW at the Site, the alternative still relies heavily on capping and institutional controls to provide long-term protection.

7.7.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.7.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 5 would include reactive sediment capping, reactive residuals cover, upland DNAPL/soil *in situ* solidification, and PRB treatment of groundwater. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes. Under this alternative, approximately 47 percent of DNAPL would be treated.

7.7.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 5, approximately 210,800 gallons of DNAPL is treated by *in situ* solidification. The amount of contaminated groundwater treated by sorption in the PRB is unknown. The amount of DNAPL treated by sorption onto the RCM caps and reactive residual covers is also unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.7.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 5 would reduce the mobility of upland DNAPL, through *in situ* solidification, by approximately 210,800 gallons or 47 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material remaining onsite would not be reduced. The effectiveness of the RCM caps and residual covers in Alternative 5 is the same as Alternative 4.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 51, 52, 49, and 5 percent, respectively. The mass flux reduction (due to the *in situ* solidification and PRB) for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 80, 81, 89, and 5 percent, respectively.

7.7.4.4 Degree to which Treatment is Irreversible

The vast majority of DNAPL in *in situ* solidification is expected to be treated and solidification treatment would be expected to be essentially irreversible. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

Like Alternatives 3 and 4, treatment of dissolved-phase contaminated groundwater migrating through the PRB is expected to be irreversible, as is treatment of DNAPL using reactive amended caps and residual covers. At present, for both technologies, the quantities of contaminants that would be sorbed are unknown.

7.7.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL treated by *in situ* solidification would remain onsite, and mixed with the soil matrix would comprise approximately 78,900 cy. As with Alternative 3, the solidified matrix is not considered to be post-treatment residual or untreated waste; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown.

Alternative 5 would include the same residuals from aquatic remedial technologies as Alternative 4.

7.7.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 5 does not satisfy the statutory preference for treatment as a primary component of the alternative because approximately 47 percent of the PTW is treated and the majority of the alternative is containment.

7.7.4.7 Alternative 5 Rating with Respect to this Criterion

Alternative 5 is rated "moderate" with respect to reduction of toxicity, mobility, or volume through treatment. Mobility of DNAPL remaining in sediments would be reduced by a combination of dredging/residual covers and RCM caps. Treatment of upland PTWs greater than 4 feet in cumulative thickness would moderately reduce the volume of contaminated groundwater, and the PRB would significantly reduce the mass flux of organic COCs to sediments.

7.7.5 *Short-Term Effectiveness*

Alternative 5 has many of the same activities as Alternatives 3 and 4. Generally, the focus of Alternative 5 is in-situ solidification of some of the DNAPL-impacted soil at Quendall and does not involve excavation directly as a remedial action for DNAPL-impacted soil. The same volume of contaminated sediment is dredged as in Alternative 4.

7.7.5.1 Protection of Community during Remedial Actions

For Alternative 5, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 25,900 cy of potentially contaminated sediment;

2) inhalation exposure to dust and vapors from excavation of 400 cy of DNAPL-impacted soil;

3) inhalation exposure to dust and vapors from in-situ solidification of 17,000 cy of DNAPL-impacted soil;

4) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 26,300 cy of potentially contaminated soils/sediment;

5) inhalation of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and

6) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

Less contaminated material will be transported off-site for disposal than with Alternative 3 because more of the DNAPL-impacted soils will be solidified in place. The same amount, 25,900 cy of contaminated sediment will be dredged and handled for off-site disposal as with Alternative 4. Implementation of Alternative 5 will not pose an increased chance of exposure because there is no increase in the amount of dredging and in-situ solidification generates less dust and air quality issues that excavation. Protective measures are the same as in Alternatives 3 and 4. Alternative 5 is not expected to cause unacceptable risks to the community.

Impacts to “quality of life” is assumed to be a concern of the neighboring community.

7.7.5.2 Protection of Workers during Remedial Actions

For Alternative 5, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and contaminated sediments during dredging of 25,900 cy of potentially contaminated sediment;

2) inhalation and dermal exposure to dust and vapors from excavation of 400 cy of DNAPL-impacted soil;

3) inhalation and dermal exposure to dust and vapors from in-situ solidification of 17,000 cy of DNAPL-impacted soil; and

4) inhalation and dermal exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 26,300 cy of potentially contaminated soils/sediment.

Alternative 5 would require the same measures to protect workers to those defined under Alternatives 3 and 4. No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. For Alternative 5 the potential risk to on-site workers may be less than with Alternatives 3 and 4. Less dust is generated and fewer potential air quality issues are expected using in-situ solidification instead of excavation for remediating upland DNAPL-impacted soils. There is no increase in the amount of contaminated sediments dredged and there is a decrease in the amount of hazardous materials to be handled and transported off-site.

7.7.5.3 Environmental Impacts

Environmental impacts associated with Alternative 5 are not expected to be any greater than with Alternatives 3 and 4. Actually, environmental impacts is likely to be less because activities associated with *in situ* solidification is expected to be easier to manage than excavation in terms of impacts to the aquatic environment. Environmental impacts to the environment is expected to be about the same as with Alternative 4.

7.7.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 2.3 years from initiation of remedial construction, slightly more quickly than with Alternative 4 (Figure 7-5). Not all RAOs would be achieved at the end of the construction period. The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would not be met within 100 years. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a "clean" sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.7.5.5 Alternative 5 Rating with Respect to this Criterion

Same as Alternative 4, Alternative 5 is rated "Moderate" with respect to short-term effectiveness.

7.7.6 *Implementability*

7.7.6.1 Technical Feasibility

Alternative 5 consists of one fewer construction elements than as in Alternative 4, for a total of seven construction elements. Alternative 5 replaces excavation of 2,800 cy upland DNAPL-impacted soil (QP-U) and DNAPL collection trenches with *in situ* solidification of 17,000 cy of DNAPL-impacted soil. Solidification, like excavation, is a proven remedial technology that has been widely used over a number of years and is considered to be technically feasible for the Quendall site. Alternative 5 incorporates the same remedial technologies containing reactive media (PRBs and RCM caps), and poses the same repair and replacement problems as in Alternative 4. PRBs and RCM caps as used on Alternative 5 and previous alternatives require repair or replacement, in perpetuity, but Alternative 5 does not include DNAPL collection trenches.

7.7.6.2 Administrative Feasibility

The administrative feasibility is the same as in Alternatives 3and 4.

7.7.6.3 Availability of Services and Materials

Necessary engineering and construction services and remedial materials are readily available.

7.7.6.4 Alternative 5 Rating with Respect to this Criterion

Implementability for Alternative 5 is "moderate" even though there are a number of construction elements, however, there is one fewer remedial technology that requires ongoing operation and maintenance, in perpetuity.

7.7.7 *Cost*

The estimated present worth cost of Alternative 5 is $47 million, including a projected $42 million for capital construction and $4.1 million (present worth) for OM&M.

7.8 Detailed Evaluation of Alternative 6

Alternative 6 is similar to Alternative 5 but provides additional treatment of PTW by expanding the solidification area to include upland DNAPL-impacted soil that exceed 2 feet of cumulative thickness (as opposed to 4 feet of cumulative thickness). Like Alternative 4, Alternative 6 includes excavation of PTWs in the QP-U area, which contains large amounts of potentially mobile DNAPL adjacent to Lake Washington. Refer to Section 6.3.6 for a detailed description.

7.8.1 *Overall Protection of Human Health and the Environment*

Alternative 6 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health (Section 7.7.1.1) and the environment (Section 7.7.1.2) as follows:

7.8.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) cannot be achieved by Alternative 6. While 91 percent of the upland PTW that causes the groundwater contamination is treated or removed in this alternative, enough remains to continue as a source of groundwater contamination for hundreds of years. Treatment of shallow groundwater leaving the uplands and being sorbed by the PRB before entering the lake would restore an unknown amount of groundwater. Overall, the groundwater plume would be reduced by 43 percent as compared to Alternative 1 (No Action). Human health risks would be addressed via institutional controls and monitoring in the same manner as Alternatives 2, 3, 4, and 5.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternatives 4 and 5.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternatives 4 and 5.

- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternatives 4 and 5.

- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Same as Alternative 5, except vapor intrusion concerns would be additionally reduced by *in situ* solidification treatment of the PTW with cumulative depths of 2 feet or more. Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs throughout the Site would also be reduced and controlled to acceptable levels by soil caps and institutional controls. Treatment of DNAPL at cumulative depths of 2 feet or more may not reduce exposure to vapors sufficiently to reduce or change institutional controls, engineering controls or capping requirements for vapor intrusion as identified in Alternatives 3 and 5.

- **HH6: Reduce Risk to Soil to Acceptable Levels.** Same as Alternative 5, except a larger area of the uplands will be treated or excavated. These areas would be noted on the appropriate institutional controls and may not require a cap. Human health risk from direct contact or incidental ingestion of COCs in soil would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. A total of approximately 142,500 cy of DNAPL and soil would be treated with *in situ* solidification and approximately 14,800 cy of soil would be excavated in the QP-U area and during construction of the funnel and gate systems.

7.8.1.2 7.7.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternatives 4 and 5.

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternatives 4 and 5.

- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternatives 4 and 5.

7.8.1.3 Alternative 6 Rating with Respect to this Criterion

Alternative 6 does not satisfy the threshold criterion for Overall Protection of Human Health and the Environment. The alternative is rated “moderate” for Short-Term Effectiveness (Section 7.8.5) and for Long-Term Effectiveness and Permanence (Section 7.8.3); however, the RAO to restore groundwater to its highest beneficial use by meeting MCL ARARs and RBCs for drinking water would not be met, nor is it a candidate for a TI waiver (Section 7.8.2). Protectiveness would be addressed via institutional controls and monitoring.

7.8.2 *Compliance with ARARs*

Alternative 6 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with the exception of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. Approximately 91 percent of the PTW that causes the groundwater contamination is removed or treated in this alternative. The extent to which MCLs would be achieved in this alternative is discussed below.

7.8.2.1 Compliance with the MCL ARAR

For Alternative 6, groundwater volume exceeding MCLs is predicted to decrease by 56 percent for benzene, 47 percent for benzo[a]pyrene and 12 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 6, the groundwater volume exceeding MCLs in the aggregate plume was predicted to decrease by roughly 50 percent relative to the No Action alternative. Unacceptable risks remain in place should exposure occur.

7.8.2.2 Technical Impracticability Waiver

It is assumed that Alternative 6 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTWs are readily accessible with currently available engineering technology.

7.8.2.3 Alternative 6 Rating with Respect to this Criterion

Alternative 6 does not satisfy the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will not be met throughout the plume nor can a TI waiver be granted.

7.8.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 6 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.8.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

Approximately 9 percent (by volume) of PTW is left in place as untreated waste; therefore DNAPL-impacted soils and sediment remain in place and untreated at 2,700 and 32,400 cy, respectively. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBCs are reduced (benzene at 56 percent, naphthalene at 41 percent, benzo[a]pyrene at 47 percent, and arsenic at 12 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur.

7.8.3.2 Adequacy and Reliability of Controls

Controls in Alternative 6 include an upland cap, a PRB (funnel and gate system), sediment caps (engineered sand cap and reactive sediment cap), reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternatives 2, 3, 4, and 5.

PRB (Funnel and Gate System). Same as Alternatives 3, 4, and 5.

Sediment Caps. Same as Alternatives 4 and 5.

Reactive Residuals Cover. Same as Alternatives 4 and 5.

ENR. Same as Alternatives 4 and 5.

Institutional Controls. Same as Alternatives 3, 4, and 5. Because some PTWs are left in place, and restoration of groundwater to meet MCLs and RBCs would not be achieved, they would be required and relied upon in perpetuity.

7.8.3.3 Alternative 6 Rating with Respect to this Criterion

Alternative 6 is rated "moderate" with respect to long-term effectiveness and permanence while it treats or removes a significant amount of the PTW at the Site, the alternative still relies heavily on capping and institutional controls to provide long-term protection.

7.8.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.8.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 6 include reactive sediment capping, reactive residuals cover, upland DNAPL/soil *in situ* solidification, and PRB treatment of groundwater. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes. Under this alternative, approximately 70 percent of DNAPL would be treated.

7.8.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 6, approximately 311,000 gallons of DNAPL is treated by *in situ* solidification. The amount of contaminated groundwater treated by sorption in the PRB is unknown. The amount of DNAPL treated by sorption onto the RCM caps and reactive residual covers is also unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.8.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 6 would reduce the mobility of upland DNAPL, through *in situ* solidification, by approximately 311,000 gallons or 70 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material would not be reduced. The effectiveness of the RCM caps and residual covers in Alternative 6 is the same as Alternatives 4 and 5.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 69, 74, 75, and 12 percent, respectively. The mass flux reduction (due to the *in situ* solidification and PRB) for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 86, 89, 94, and 5 percent, respectively. However, the PRB can only be completely effective if long-term monitoring and maintenance is successfully implemented and institutional controls are observed in perpetuity.

7.8.4.4 Degree to which Treatment is Irreversible

The vast majority of DNAPL in *in situ* solidification is expected to be treated and solidification treatment would be expected to be essentially irreversible. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

Like Alternatives 4 and 5, treatment of dissolved-phase contaminated groundwater migrating through the PRB is expected to be irreversible as is treatment of DNAPL and dissolved constituents using reactive amended caps and residual covers. At present, for both technologies, the quantities of contaminants that would be sorbed are unknown.

7.8.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL treated by *in situ* solidification would remain onsite, and mixed with the soil matrix would comprise approximately 142,500 cy. As with Alternative 3, the solidified matrix is not considered to be post-treatment residual or untreated waste; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown.

Alternative 6 would include the same residuals from aquatic remedial technologies as Alternatives 4 and 5.

7.8.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 6 does satisfy the statutory preference for treatment as a primary component of the alternative because 68 percent of the PTW is treated.

7.8.4.7 Alternative 6 Rating with Respect to this Criterion

Alternative 6 is rated “moderate” with respect to reduction of toxicity, mobility, or volume through treatment. Mobility of DNAPL remaining in sediments would be reduced by a combination of dredging/residual covers and RCM caps. Treatment of upland PTWs greater than 2 feet in cumulative thickness would moderately reduce the volume of contaminated groundwater, and the PRB would significantly reduce the mass flux of organic COCs to sediments.

7.8.5 *Short-Term Effectiveness*

Alternative 6 has the same activities as Alternative 5. Alternative 6 includes excavation and solidification of larger volumes of DNAPL-impacted soil. The same volume of contaminated sediment is dredged as in Alternatives 4 and 5.

7.8.5.1 Protection of Community during Remedial Actions

For Alternative 6, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 25,900 cy of potentially contaminated sediment;

2) inhalation exposure to dust and vapors from excavation of 2,700 cy of DNAPL-impacted soil;

3) inhalation exposure to dust and vapors from *in situ* solidification of 25,100 cy of DNAPL-impacted soil;

4) inhalation exposure to dust or air emissions may also occur from handling and stockpiles for transport off-site, by truck, of 28,600 cy of potentially contaminated soils/sediment.

5) inhalation of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and

6) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

Alternative 6 would solidify 8,100 cy more of DNAPL-impacted soils than Alternative 5 but close to the same amount as in Alternative 4. In Alternative 6, an additional 2,300 cy of DNAPL-impacted soil would be excavated and transported off-site than with Alternative 5, but it is close to the same amount as in Alternative 4. The same amount, 25,900 cy of contaminated sediment will be dredged and handled for off-site disposal as with Alternatives 4 and 5.

Implementation of Alternative 6 will not pose an increased chance of exposure because there is no significant increase in the amount of hazardous material handled than in previous alternatives. Alternative 6 is not expected to cause unacceptable risks to the community.

Impacts to “quality of life” is assumed to be a concern of the neighboring community.

7.8.5.2 Protection of Workers during Remedial Actions

For Alternative 6, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and contaminated sediments during dredging of 25,900 cy of potentially contaminated sediment;

2) inhalation and dermal exposure to dust and vapors from excavation of 2,700 cy of DNAPL-impacted soil;

3) inhalation and dermal exposure to dust and vapors from *in situ* solidification of 25,100 cy of DNAPL-impacted soil; and

4) inhalation and dermal exposure to dust or air emissions may also occur from handling and stockpiles for transport off-site, by truck, of 28,600 cy of potentially contaminated soils/sediment.

Alternative 6 would require the same measures to protect workers to those defined under Alternatives 3, 4 and 5. No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. For Alternative 6, the potential risk to on-site workers may be less than with Alternatives 3 and 4. Less dust is generated and fewer potential air quality issues are expected using in-situ solidification instead of excavation for remediating upland DNAPL-impacted soils. There is no increase in the amount of contaminated sediments dredged and there is a decrease in the amount of hazardous materials to be handled and transported off-site.

7.8.5.3 Environmental Impacts

Environmental impacts associated Alternative 6 is expected to be similar, with a moderate rating, to those with Alternatives 4 and 5.

7.8.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 3.2 years from initiation of remedial construction, slightly longer than Alternative 4 and 5 (Figure 7-5). Not all RAOs would be achieved at the end of the construction period. The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would not be met within 100 years. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.8.5.5 Alternative 6 Rating with Respect to this Criterion

Alternative 6 is rated the same as Alternative 5, as “moderate”.

7.8.6 *Implementability*

7.8.6.1 Technical Feasibility

Alternative 6 has one additional construction element than Alternative 5 for a total of eight construction elements. Similar to previous alternatives, Alternative 6 relies on the use of multiple construction elements. The difference between Alternative 5 and 6 is that under Alternative 6, 2,700 cy of upland DNAPL-impacted soil (QP-U) is excavated rather than solidified. Alternative 6 solidifies a total of 25,100 cy of DNAPL-impacted soil compared to the total of 17,000 cy for Alternative 5. Solidification and excavation are proven remedial technologies that have been widely used over a number of years and are considered to be technically feasible for the Quendall site. Alternative 6 incorporates the same remedial technologies containing reactive media (PRBs and RCM caps), and poses the same repair and replacement problems as in Alternatives 4 and 5. PRBs and RCM caps as used on Alternative 6 and previous alternatives require repair or replacement, in perpetuity.

7.8.6.2 Administrative Feasibility

The administrative feasibility of Alternative 6 is the same as for Alternative 5.

7.8.6.3 Availability of Services and Materials

Availability of services and materials is the same as Alternative 5.

7.8.6.4 Alternative 6 Rating with Respect to this Criterion

Implementability for Alternative 6 is “moderate” even though there are a high number of construction elements, there are fewer remedial technologies that require ongoing maintenance and repair and replacement, in perpetuity.

7.8.7 *Cost*

The estimated present worth cost of Alternative 6 is $61 million, including a projected $57 million for capital construction and $4.1 million (present worth) for OM&M.

7.9 Detailed Evaluation of Alternative 7

Alternative 7 involves solidification of all known upland PTWs and removal and on-site treatment of all known sediment PTWs. The purpose of treating or removing all PTW is to eliminate sources of groundwater contamination to a greater extent than other previous alternatives. Because all known PTWs are being addressed, upland DNAPL collection trenches and the PRB are not included in this alternative. Containment measures described in Alternative 2, except RCM caps, are also included in this alternative to maintain protectiveness and provide additional source control. Residual covers will be placed over all dredged sediment areas. Refer to Section 6.3.7 for a detailed description.

7.9.1 *Overall Protection of Human Health and the Environment*

Alternative 7 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment (see Sections 4.2.2 and 4.2.3, respectively) as follows:

7.9.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) may be achieved by Alternative 7. It is the intent to address 100 percent of the PTW that causes the groundwater contamination in this alternative, and minimize or eliminate the size of the plume for one or more of the COCs. Overall, the groundwater plume would be reduced by 80 percent as compared to Alternative 1 (No Action).[15] Human health risks would be addressed in the same manner as previous alternative until COCs are reduced to acceptable levels.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 6; except that areas with RCM caps would be replaced with residual covers.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 6; except that areas with RCM caps would be replaced with residual covers.

- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 6; except that areas with RCM caps would be replaced with residual covers.

- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs would be greatly reduced, especially in buildings constructed over areas of the Site treated by *in situ* solidification. Institutional controls would still require that any future use that results in human occupation in enclosed spaces will require an assessment for

[15] See Section 7.8.2.1 for a discussion of the uncertainty of modeling results, particularly for Alternatives 7 through 10 that address all PTW source materials.

potential vapor intrusion risks and, if necessary, require engineering controls to eliminate exposure to vapors.

- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Human health risk from direct contact or incidental ingestion of COCs in soil would be greatly reduced by addressing all upland PTWs via *in situ* solidification. Exposure to any remaining unacceptable levels of COCs would be reduced and controlled to acceptable levels through a combination of a soil cap and institutional controls. A total of approximately 241,300 cy of DNAPL and soil would be treated with *in situ* solidification.

7.9.1.2 7.8.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 6; except that areas with reactive amended caps would be replaced with residual covers.

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 6; except that areas with reactive amended caps would be replaced with residual covers.

- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 6; except that areas with reactive amended caps would be replaced with residual covers.

7.9.1.3 Alternative 7 Rating with Respect to this Criterion

Alternative 7 satisfies the threshold criterion for Overall Protection of Human Health and the Environment. It is rated “low” for Short-Term Effectiveness (Section 7.9.5) because of the extensive upland and in-water construction upland and in-water activities occurring over a multi-year period; however, the alternative is rated “high” for Long-Term Effectiveness and Permanence (Section 7.9.3) because all PTWs are removed or treated. It also complies with all ARARs, with some uncertainty about fully achieving MCLs for one or more COCs; however, because all PTWs are addressed, it would be a candidate for a TI waiver (Section 7.9.2).

7.9.2 *Compliance with ARARs*

Alternative 7 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with some uncertainty about meeting the requirements of the SDWA, which requires achievement of groundwater MCLs throughout the Site.

Because all identified PTW sources are addressed, Alternative 7 could substantially meet all or most MCLs if not completely. As discussed in Section 7.1.1.2, there are many uncertainties associated with the modeling associated with predictions of plume reductions by alternative. Also, in Section 7.1.1.2, information is provided that explains, based on the known properties of the COCs and site conditions and remedial efficacy of the remedial technology the reason for assuming significant if not complete compliance with some or all MCLs. The extent to which MCLs would be achieved in this alternative is discussed below.

7.9.2.1 Compliance with the MCL ARAR

For Alternative 7, groundwater volume exceeding MCLs is predicted to decrease by 97 percent for benzene, 78 percent for benzo[a]pyrene, and 21 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 7, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by roughly 79 percent relative to the No Action alternative.

As discussed in Section 7.1.1.2, EPA views the groundwater modeling results as conservative such that Alternative 7 would either minimize or eliminate the size of the contaminated plume for one or more of the COCs with MCLs within a reasonable timeframe.

7.9.2.2 Technical Impracticability Waiver

It is uncertain whether Alternative 7 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is assumed that a TI waiver would be granted if monitoring data indicate that an MCL may not be met in a certain area of the plume. EPA believes that a TI waiver would be granted because all PTWs identified during site investigations would be treated or removed under this alternative.

7.9.2.3 Alternative 7 Rating with Respect to this Criterion

Alternative 8 satisfies the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will either be met throughout the plume or a TI waiver may be granted.

7.9.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 7 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.9.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

For Alternative 7, none of the PTW is left in place as untreated waste. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBC are reduced (benzene at 97 percent, naphthalene at 89 percent, benzo[a]pyrene at 78 percent, and arsenic at 21 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur, until COCs are returned to acceptable levels.

7.9.3.2 Adequacy and Reliability of Controls

Controls in Alternative 7 include an upland cap, engineered sand caps, reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. An upland cap may not be needed once all PTW has been addressed.

Engineered Sand Caps. Same as Alternative 6, except some institutional controls may not be needed in perpetuity because of significant contaminant mass flux reduction because all PTW is being addressed.

Reactive Residuals Cover. Same as Alternative 6 except all PTW is dredged, therefore the areal extent of reactive residual covers is extended.

ENR. Same as Alternative 6.

Institutional Controls. Same as Alternative 6. Because all of the PTWs identified during site investigations are treated or removed, and there are fewer engineering controls needed to protect contained contamination, there is less reliance on institutional controls for Alternative 7 than for Alternatives 2 through 6. In addition, some institutional controls may not be needed in perpetuity (e.g., the engineered sand cap for upwelling contaminated groundwater).

7.9.3.3 Alternative 7 Rating with Respect to this Criterion

Alternative 7 is rated “high” with respect to long-term effectiveness and permanence because of its reliance on treatment and removal technologies to address all PTWs.

7.9.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.9.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 7 include a reactive residuals cover and upland DNAPL/soil *in situ* solidification. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes. Under this alternative, approximately 85 percent of DNAPL would be treated.

7.9.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 7, approximately 377,500 gallons of DNAPL is treated by *in situ* solidification. The amount of DNAPL treated by sorption onto the reactive residual covers is unknown. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.9.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 7 would reduce the mobility of upland DNAPL, through *in situ* solidification, by approximately 377,500 gallons or 85 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material would not be reduced. The remaining 15 percent would be removed from the aquatic environment via dredging and landfilled.

The reactive residual covers would be expected to be 100 percent effective at controlling DNAPL mobility from underlying sediments into the surface waters of Lake Washington; however, only a negligible amount of DNAPL is expected to be in contact with the caps and covers. The residual covers should also be 100 percent effective in treating and reducing the volume of dissolved-phase contaminants flowing into the lake; however, the volume of dissolved-phase contaminants treated by the caps and covers is unknown. The reactive residual covers can only completely effective if long-term monitoring and maintenance is successfully implemented and institutional controls are observed in perpetuity.

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 100, 100, 98, and 24 percent, respectively. The mass flux reduction (due to the *in situ* solidification) for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 100, 100, 99, and 6 percent, respectively (see Figure 7-3).

7.9.4.4 Degree to which Treatment is Irreversible

The vast majority of DNAPL in *in situ* solidification is expected to be treated and solidification treatment would be expected to be essentially irreversible. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

Treatment of DNAPL and dissolved constituents using reactive residual covers containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, the quantities that would be sorbed are unknown.

7.9.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL treated by *in situ* solidification would remain onsite, and mixed with the soil matrix would comprise approximately 241,300 cy. As with Alternative 3, the solidified matrix is not considered to be post-treatment residual or untreated waste; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown.

Alternative 7 would differ from Alternative 6 in there are other residuals from upland technologies (no PRB) and fewer residuals from aquatic remedial technologies (no reactive amended caps, only residual covers).

7.9.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 7 satisfies the statutory preference for treatment as a primary component of the alternative because the majority of the alternative includes treatment.

7.9.4.7 Alternative 7 Rating with Respect to this Criterion

Alternative 7 is rated “high” with respect to reduction of toxicity, mobility, or volume through treatment because a large fraction of PTWs would be treated. The volume of contaminated groundwater and mass flux of organic COCs to sediments would be greatly reduced over time.

7.9.5 *Short-Term Effectiveness*

Alternative 7 has generally the same activities as Alternative 6. Alternative 7 does not involves excavation of DNAPL-impacted soil, instead all DNAPL-impacted soil is solidified. All DNAPL-impacted sediment is dredged; twice the amount as dredged in Alternative 6.

7.9.5.1 Protection of Community during Remedial Actions

Alternative 7 has some of the same activities as Alternative 6. For Alternative 7, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 58,300 cy of potentially contaminated sediment;
2) inhalation exposure to dust and vapors from *in situ* solidification of 30,500 cy of DNAPL-impacted soil;
3) inhalation exposure to dust or air emissions from handling and stockpiles for transport off-site, by truck, of 58,300 cy of potentially contaminated soils/sediment;
4) inhalation of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and
5) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

In Alternative 7 an additional 5,400 cy of DNAPL-impacted soils are solidified than with Alternative 6 but Alternative 7 does not include excavation of DNAPL-impacted soils as Alternative 6 does. Approximately, twice the amount (32,400 cy more) of contaminated sediments are dredged and transported off-site with Alternative 7 than as with Alternative 6.

Implementation of Alternative 7 may cause an increased concern regarding air quality because of the increased amount of contaminated sediments to be dredged compared with Alternatives 3, 4, and 6. However, the areas that will be dredged in Alternative 7 that will not be dredged in Alternative 2 and 3 contain much lower volumes of DNAPL and lower concentrations of contaminated sediments; therefore, the likelihood that an increase in risk due to air quality exceedance is low. Also, in Alternative 7, concerns about the generation of dust is low compared to other previous alternatives where excavation of DNAPL-impacted soil is included such as in Alternative 6. Solidification is not expected to generate as much dust as excavation and is expected not to be a concern for the nearby community. Alternative 7 would require similar protective measures as those defined under Alternatives 5 and 6. Alternative 7 is not expected to cause unacceptable risks to the community.

Impacts to “quality of life” are assumed to be a concern of the neighboring community.

7.9.5.2 Protection of Workers during Remedial Actions

For Alternative 7, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and contaminated sediment from during dredging of 58,300 cy of potentially contaminated sediment;

2) inhalation and dermal exposure to dust and vapors from *in situ* solidification of 30,500 cy of DNAPL-impacted soil; and

3) inhalation and dermal exposure to dust or air emissions may also occur from handling and stockpiles for transport off-site, by truck, of 58,300 cy of potentially contaminated soils/sediment.

Alternative 7 would require the same measures to protect workers to those defined under Alternatives 3, 4, 5, and 6. No unacceptable health risks to on-site workers are expected even though exposures may go beyond those expected for the neighboring community. For Alternative 7 the potential risk to on-site workers is expected to be similar to Alternatives 5 and 6. There is a very slight increase in the amount of DNAPL-impacted soils to be solidified but there will not be concerns about dust generated from excavation as in Alternative 6. There is a significant increase in the amount of dredging of contaminated sediments that greatly increases concerns about exposure; however, the areas contributing to the increase in dredging volumes contain much lower volumes of DNAPL and lower concentrations of contaminated sediments. Actual risk due to air quality concerns is not expected to increase beyond that of Alternatives 4, 5, and 6.

7.9.5.3 Environmental Impacts

Alternative 7 requires dredging approximately twice the volume of contaminated sediments as Alternative 6. Alternative 7 involves the same amount of capping as Alternative 6. However, the assumed increase in adverse impact to aquatic habitat caused by dredging is off-set by impacts caused by capping in previous alternatives. For example, Alternative 6 involves using RCM caps over twice the area of sediments as Alternative 7. The area of sediments either dredged and/or capped/covered is the same throughout all the alternatives; however, dredging can result in the generation of contaminated residuals. The use of a residuals cover, which will mitigate the impact of residuals, will less adversely impact the aquatic environment than RCM caps used in previous alternatives.

Impacts to the environment from the uplands is expected to decrease over previous alternative because excavation of DNAPL-impacted and contaminated soil are not a part of Alternative 7. Increased *in situ* solidification in the uplands, when considering that there will be no excavation of DNAPL-impacted or contaminated soil, presents a lower impact to the environment than Alternative 6.

7.9.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 4 years from initiation of remedial construction, which is longer by a half of a year, than Alternative 6 (Figure 7-5). Not all RAOs would be achieved at the end of the construction period.

The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would require an uncertain period of time to be met following the end of construction; however, it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver would be granted, if necessary..

The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a "clean" sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.9.5.5 Alternative 7 Rating with Respect to this Criterion

Alternative 7 is rated "moderate" with respect to short-term effectiveness. There is a large increase in the amount of potentially contaminated sediments to be dredged and handled for off-site disposal; however, there are no DNAPL-impacted soils to be excavated and disposed off-site. No unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. However, greater adverse impacts are expected in the aquatic environment because of the greater extent of dredging and the generation of contaminated residuals associated with Alternative 7; however, habitat recovery is expected to occur relatively quickly.

7.9.6 *Implementability*

7.9.6.1 Technical Feasibility

Alternative 7 consists of fewer construction elements and remedial technologies than most previous alternatives. Alternative 7 consists of: 1) placing and repair/placement of engineered sand caps and ENR cover; 2) dredging and off-site disposal of all DNAPL-impacted sediments (58,300 cy of sediment); and 3) *in situ* solidification of all DNAPL-impacted soil (30,500 cy) and additional clean and contaminated soil in the DNAPL "footprint" (totaling 241,300 cy). An upland soil cap may not be needed in Alternative 7. All are proven and reliable technologies to implement and operate. Dredging can generate contaminated residuals but with the use of expert operators and "tried and true" dredging practices, the generation of residuals can be minimized and remediated with the application of a residuals cover.

The technical feasibility of the upland remedial technologies is the same as Alternative 5, and the technical feasibility of the aquatic remedial technologies is the same as Alternative 6.

7.9.6.2 Administrative Feasibility

Alternative 7 is expected to have some of the fewest administrative feasibility challenges because shoreline caps that can change the bathymetry will not be placed in the aquatic nearshore area.

7.9.6.3 Availability of Services and Materials

Necessary engineering and construction services are readily available.

7.9.6.4 Alternative 7 Rating with Respect to this Criterion

Alternative 7 is rated "high" with respect to implementability because Alternative 7 involves fewer construction elements of most of the alternatives. The technologies are well understood and have been used for many years. Environmental dredging is a more recent technique but as experience with environmental dredging has increased, better practices have developed to minimize the generation of contaminated residuals and the management of such residuals, as evidenced in recent local dredging projects, such as the Boeing project in the Duwamish River. Engineered caps are relatively easy to repair or replace unlike RCM caps. Monitoring is expected to be relatively simple to implement given that DNAPL-impacted media will be treated or removed, unlike other alternatives that leave large amounts of DNAPL-impacted media in place in perpetuity. Lengthy construction schedules may results in more schedule modifications than other alternatives, such as Alternative 2, with few construction elements. Alternatives with more construction elements could also result in schedule complications because of more complicated coordination of multiple remedial activities sometimes in a short period of time.

7.9.7 *Cost*

The estimated present worth cost of Alternative 7 is $80 million, including a projected $78 million for capital construction and $2.7 million (present worth) for OM&M.

7.10 Detailed Evaluation of Alternative 8

Alternative 8 involves removal and on-site treatment of upland and sediment PTWs. The upland remedy components differ from Alternative 7 in that PTWs are removed and thermally treated *ex situ* on-site instead of treated with *in situ* stabilization. As with Alternative 7, because all known PTWs are being addressed, upland DNAPL collection trenches and the PRB are not included in this alternative. The aquatic remedy components are identical to Alternative 7. Containment measures described in Alternative 2, except RCM capping[16], are also included in this alternative to maintain protectiveness and provide additional source control. Refer to Section 6.3.8 for a detailed description.

7.10.1 *Overall Protection of Human Health and the Environment*

Alternative 8 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment (see Sections 4.2.2 and 4.2.3, respectively) as follows:

7.10.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) may be achieved by Alternative 8. It is the intent to address 100 percent of the PTW that causes the groundwater contamination in this alternative, and minimize or eliminate the size of the plume for one or more of the COCs. Overall, the groundwater plume would be reduced by 81 percent as compared to Alternative 1 (No Action).[17] Human health risks would be addressed in the same manner as Alternative 2 until COCs are reduced to acceptable levels.

[16] RCM capping is not included in Alternative 8 because sediment PTWs are removed.

[17] See Section 7.8.2.1 for a discussion of the uncertainty of modeling results, particularly for Alternatives 7 through 10 that address all PTW source materials.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 7.
- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 7.
- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 7.
- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Same as Alternative 7.
- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Same as Alternative 7. A total of approximately 210,100 cy of DNAPL and soil would be excavated and thermally treated on site.

7.10.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 7.
- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 7.
- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 7.

7.10.1.3 Alternative 8 Rating with Respect to this Criterion

Alternative 8 satisfies the threshold criterion for Overall Protection of Human Health and the Environment. While it is rated “low” for Short-Term Effectiveness (Section 7.10.5) because of the extensive upland and in-water construction upland and in-water activities occurring over a multi-year period, the alternative is rated “high” for Long-Term Effectiveness and Permanence (Section 7.10.3) because all PTWs are removed or treated. It also complies with all ARARs, with some uncertainty about achieving MCLs for all COCs; however, because all PTWs are addressed, it would be a candidate for an ARAR waiver (Section 7.10.2).

7.10.2 *Compliance with ARARs*

As discussed in Section 7.1.1.2, Alternative 8 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with uncertainty about meeting the requirements of the SDWA, which requires achievement of groundwater MCLs throughout the Site. Because all PTW sources are removed, Alternative 8 could substantially meet all or most MCLs if not completely. The extent to which MCLs would be achieved in this alternative is discussed below.

7.10.2.1 Compliance with the MCL ARAR

For Alternative 8, groundwater volume exceeding MCLs is predicted to decrease by 100 percent for benzene, 33 percent for benzo[a]pyrene, and 11 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 8, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by roughly 75 percent relative to the No Action alternative. As discussed in Section 7.1.1.2, EPA views the groundwater modeling results as conservative such that Alternative 8 would either minimize or eliminate the size of the contaminated plume for one or more of the COCs with MCLs within a reasonable timeframe.

7.10.2.2 Technical Impracticability Waiver

It is uncertain whether Alternative 8 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is assumed that a TI waiver would be granted if monitoring data indicate that MCLs may not be met, since all known PTWs would be addressed under this alternative.

7.10.2.3 Alternative 8 Rating with Respect to this Criterion

Alternative 8 satisfies the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will either be met throughout the plume or a TI waiver may be granted.

7.10.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 8 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.10.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

For Alternative 8, none of the PTW is left in place as untreated waste. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBC are reduced (benzene by 100 percent, naphthalene by 100 percent, benzo[a]pyrene by 33 percent, and arsenic by 11 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur, until COCs are returned to acceptable levels.

7.10.3.2 Adequacy and Reliability of Controls

Controls in Alternative 8 include an upland cap, engineered sand caps, reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. Same as Alternative 7.

Engineered Sand Caps. Same as Alternative 7.

Reactive Residuals Cover. Same as Alternative 7.

ENR. Same as Alternative 7.

Institutional Controls. Same as Alternative 7. Because all of the PTWs identified during site investigations are treated or removed, and there are fewer engineering controls needed to protect contained contamination, there is less reliance on institutional controls for Alternative 8 than for Alternatives 2 through 6. In addition, some institutional controls may not be needed in perpetuity (e.g., the engineered sand cap for upwelling contaminated groundwater).

7.10.3.3 Alternative 8 Rating with Respect to this Criterion

Alternative 8 is rated "high" with respect to long-term effectiveness and permanence because of its reliance on removal technologies to address all PTWs.

7.10.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.10.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 8 include a reactive residuals cover (same as Alternative 7) and on-site thermal treatment for all PTW soil and sediment (different than Alternative 7, which uses *in situ* solidification for upland PTW treatment). Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.10.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 8, approximately 445,100 gallons of DNAPL is treated by on-site thermal treatment. The amount of contaminated groundwater treated by sorption onto reactive residual covers is unknown but expected to be minimal. The intent of this alternative is to treat all PTWs at the Site. However it is likely that some residual contamination could remain given the complexity of the Site and volume of treatment involved under this alternative.

7.10.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 8 would reduce the toxicity, mobility, and volume of upland DNAPL that is treated. Thermal treatment effectiveness for arsenic is uncertain. Pilot-scale testing would be completed to optimize treatment parameters such as temperature and residence time, and to determine the reduction in concentrations that could be achieved. For the purposes of this FS, it is assumed that thermal treatment would remove DNAPL but that the treated soil may still exceed PRGs and require containment (such as capping).

Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 100, 100, 92, and 13 percent, respectively. The mass flux reduction for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 100, 100, 99, and 6 percent, respectively (see Figure 7-3).

The degree of expected reductions in toxicity, mobility, and volume from the reactive residual covers is the same as for Alternative 7.

7.10.4.4 Degree to which Treatment is Irreversible

Organic contaminant thermal treatment is irreversible.

Treatment of DNAPL and dissolved constituents using reactive residual covers containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, the quantities that would be sorbed are unknown.

7.10.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL-impacted soil and sediment treated thermally would remain onsite, and mixed with the soil/sediment matrix would comprise approximately 268,400 cy. Residual contaminant concentrations in soil would be expected to be low but may exceed PRGs depending on the effectiveness of treatment.

7.10.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 9 satisfies the statutory preference for treatment as a primary component of the alternative because the majority of the alternative includes treatment.

7.10.4.7 Alternative 8 Rating with Respect to this Criterion

Alternative 8 is rated “high” with respect to reduction of toxicity, mobility, or volume through treatment. Essentially all PTWs would be treated to greatly reduce toxicity and mobility of contaminants. The volume of contaminated groundwater and the contaminant mass flux to sediments would be greatly reduced over time.

7.10.5 *Short-Term Effectiveness*

Alternative 8 has some of the same activities as Alternative 7. Alternative 8 does not involve solidification of DNAPL-impacted soil, instead all DNAPL-impacted soil is excavated and treated on-site. All DNAPL-impacted sediment is dredged and treated on-site.

7.10.5.1 Protection of Community during Remedial Actions

For Alternative 8, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 58,300 cy of potentially contaminated sediment;

2) inhalation exposure to dust and vapors from excavation of 30,500 cy of DNAPL-impacted soil;

3) inhalation exposure to air emissions from on-site treatment of 88,800 cy of potentially contaminated soils/sediment;

4) inhalation of dust generated from the import and handling of clean material to cap up to 22 acres of soil, although a smaller area may be capped, which would be determined during remedial design; and

5) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean material to cap/cover 29.4 acres of sediment.

Alternative 8 involves excavation and on-site thermal treatment of 30,500 cy of DNAPL-impacted soils as opposed to Alternative 7 where the 30,500 cy would instead be solidified on-site. The amount of DNAPL-impacted soil that is excavated and thermally treated on-site in Alternative 8 is over 10 times greater than the amount excavated and disposed off-site in Alternative 6 and previous alternatives (up to 2,800 cy for Alternative 4). Since all materials are treated on-site, no materials would be trucked off-site. Neighboring communities maybe exposed to increased amounts of dust caused by excavation of DNAPL-impacted soil; however, continuous ongoing EPA oversight and monitoring will mitigate the extent that exposure may occur.

Alternative 8 dredges and caps/covers the same acreage of contaminated sediments as in Alternative 7. The contaminated sediments will be thermally treated on-site instead of being trucked off-site for disposal. None of the previous alternatives thermally treat contaminated waste on-site. Air emissions are a concern for thermal treatment of contaminated soil and sediment; however, very stringent air standards exist for controlling air emissions from treatment facilities.

Implementation of Alternative 8 is not expected to increase a concern for air emissions from the dredging activity compared to Alternative 7 because the same amount of contaminated sediments are being dredged for both alternatives. As with Alternative 7, the increased volume of contaminated sediments dredged may cause an increased concern regarding air quality because of the increased amount dredged compared with Alternatives 3, 4, and 6. However, the areas that will be dredged in Alternative 7 and 8 that were not dredged, in other previous alternative, contain lower amounts of DNAPL and lower concentrations of contaminated sediments; therefore, the likelihood that an increase in risk due to air quality exceedance is likely low.

Alternative 8 is not expected to cause unacceptable risks to the community because of the availability of the protective procedures and enforceable requirements. Safe levels of exposure to hazardous substances will be identified from existing regulations or risk-based calculations and included in Site operation plans. Continuous monitoring for COCs for all appropriate on-site activities, such as thermal treatment and excavation will be required and overseen by EPA personnel.

Impacts to "quality of life" are assumed to be a concern of the neighboring community.

Alternative 8 would require protective measures in addition to those identified under Alternative 7 based on the addition of a large upland excavation component and on-site thermal treatment facility.

7.10.5.2 Protection of Workers during Remedial Actions

For Alternative 8, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation and dermal exposure to vapors and contaminated sediment during dredging of 58,300 cy of potentially contaminated sediment;
2) inhalation and dermal exposure to dust and vapors from excavation of 30,500 cy of DNAPL-impacted soil;
3) inhalation and dermal exposure to dust or air emissions from handling and stockpiles for on-site thermal treatment, of 268,400 cy of potentially contaminated soils/sediment (88,800 cy of DNAPL-impacted soils/sediment); and
4) inhalation exposure to air emissions from on-site treatment of 268,400 cy of soils/sediment (88,800 cy of DNAPL-impacted soils/sediment).

Alternative 8 includes on-site treatment of contaminated media. The addition of thermal treatment will involve more handling and stockpiling of contaminated soils and sediment than previous alternatives; however, worker exposure can be mitigated by use of protective clothes/gear, engineering controls, and use of BMPS, as will be specified in the site safety plan and enforced by EPA. Construction Quality Assurance and Control Plans will be required. One focus of these plans is the prevention of worker exposure to contaminated media by direct contact or by the inhalation route.

On-site workers may also be exposed to increased amounts of dust caused by the excavation of DNAPL-impacted soil; however, the use of appropriate protective clothing, equipment, such as dust masks, and BMPs would be expected to mitigate potential risks associated with dust containing contaminated soil.

Similar measures to protect workers in Alternatives 6 and 7 will also be used with Alternative 8.

7.10.5.3 Environmental Impacts

The environmental impacts of Alternative 8 would be similar to Alternative 7. The use of on-site thermal treatment is not expected to pose an additional threat to the upland and aquatic environments. Air emissions and the potential increase of on-site handling of contaminated media can be controlled and managed so not to pose an adverse impact to the upland and aquatic environments.

7.10.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 4.5 years from initiation of remedial construction, longer by a half of a year, than Alternative 7 (Figure 7-5). Not all RAOs would be achieved at the end of the construction period. The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would require an unknown period of time to be met following the end of construction; however, it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver would be granted, if necessary. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.10.5.5 Alternative 8 Rating with Respect to this Criterion

Alternative 8 is rated “low” with respect to short-term effectiveness. There is no change in the amount of potentially contaminated sediments to be dredged. On-site thermal treatment may cause of higher concern for worker exposure because of assumed increased handling and stockpiling of contaminated media. No unacceptable risk is expected to the community or workers even though DNAPL-impacted soil will be excavated instead of solidified because of the use of protective equipment and practices. Impacts to the aquatic environment are expected to be similar to Alternative 7.

7.10.6 *Implementability*

7.10.6.1 Technical Feasibility

Alternative 8 includes many of the same remedial technologies that have been incorporated into previous alternatives, with the exception of on-site thermal treatment. Alternative 8 incorporates on-site thermal treatment as the disposal method instead of off-site disposal as used in previous alternatives. Specifically, Alternative 8 consists of: 1) placing and repair/placement of engineered sand caps and ENR cover; 2) dredging all DNAPL-impacted sediments (58,300 cy); 3) excavation of 30,500 cy of DNAPL-impacted soil along with 179,600 cy of non-DNAPL-impacted soil; and 4) on-site thermal treatment and backfill of 268,400 cy of contaminated soil and sediment (88,800 cy of DNAPL-impacted soils/sediment). An upland soil cap may not be required depending on the post-treatment sampling results of the thermally treated soil and sediment.

Alternative 8 incorporates relatively few construction elements. They are proven and commonly used technologies such as excavation, dredging and thermal treatment.

Excavation as conducted in Alternative 8, may present some implementability challenges just due to the size of the area to be excavated, in the dry, requiring extensive shoring and dewatering systems.

Thermal treatment can pose implementability concerns. Thermal treatment is technically feasible for treatment of organic compounds; however, thermal treatment requires extensive monitoring throughout its operation. On-site thermal treatment would require air emission controls and monitoring which are routine but require a series of test runs to adjust operational specifications to target for the COCs being treated at concentrations found in excavated media.

Thermal treatment is not successful with metals such as arsenic. An upland cap may be required if post-excavation sampling indicates exceedance of arsenic cleanup numbers. However, it is expected that arsenic in groundwater is largely present due to the high organic content of the soils such as DNAPL. Once the DNAPL is treated in soil, the arsenic concentrations are expected to be reduced to acceptable levels in the Shallow Aquifer.

Implementation of dredging in Alternative 8 is the same as in Alternative 7.

7.10.6.2 Administrative Feasibility

The administrative feasibility of the excavation and dredging components of Alternative 8 would similar to other alternatives that use these technologies. The same monitoring and enforcement of air emissions are expected to not cause any significant administrative issues than in the other alternatives. EPA will conduct the oversight and ensure that all substantive requirement are met reducing to eliminating much coordination with other agencies. The requirement for permits is not required for Superfund work.

7.10.6.3 Availability of Services and Materials

The local availability of vendors and equipment for on-site thermal treatment may be limited, although thermal treatment is frequently used in the Northwest. Some specialized equipment and custom materials (e.g., sheet piles for excavation) would be required and are not expected to pose any significant or inordinate problems with lead time or transportation.

7.10.6.4 Alternative 8 Rating with Respect to this Criterion

Alternative 8 is rated "low" with respect to implementability. Use of on-site thermal treatment and extensive shoring and dewatering efforts are expected to pose technical challenges, such as continuous 24-hour operation of thermal equipment and dewatering pumps.

7.10.7 *Cost*

The estimated present worth cost of Alternative 8 is $140 million, including a projected $137 million for capital construction and $2.7 million (present worth) for OM&M.

7.11 Detailed Evaluation of Alternative 9

Alternative 9 includes removal or treatment of soil and sediment that is likely to act as a long-term source of groundwater contamination above MCLs, including PTWs and soils and sediments contaminated with recalcitrant compounds (e.g., arsenic and benzo[a]pyrene). Refer to Section 6.3.9 for a detailed description. The objective of Alternative 9 is to remove or treat PTWs and to restore groundwater to its highest beneficial use (drinking water) to the maximum extent possible within the shortest timeframe.

7.11.1 *Overall Protection of Human Health and the Environment*

Alternative 9 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment (see Sections 4.2.2 and 4.2.3, respectively) as follows:

7.11.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) may be achieved by Alternative 9. It is the intent to address 100 percent of the PTW that causes the groundwater contamination in this alternative, and remove Shallow Aquifer materials outside the DNAPL footprint where benzo(a)pyrene and arsenic exceed MCLs. Overall, the groundwater plume would be reduced by 77 percent as compared to Alternative 1 (No Action).[18] Human health risks would be addressed in the same manner as Alternative 2 until COCs are reduced to acceptable levels.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

[18] See Section 7.8.2.1 for a discussion of the uncertainty of modeling results, particularly for Alternatives 7 through 10 that address all PTW source materials.

- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs would be mitigated by excavation or treatment of all contaminated soil.

- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Human health risk from direct contact or incidental ingestion of COCs in soil would be mitigated by addressing all contaminated soil. A total of approximately 362,900 cy of DNAPL and soil would be treated with *in situ* solidification and approximately 342,500 cy of DNAPL and soil would be excavated and thermally treated on-site.

7.11.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

7.11.1.3 Alternative 9 Rating with Respect to this Criterion

Alternative 9 satisfies the threshold criterion for Overall Protection of Human Health and the Environment. It is rated “low” for Short-Term Effectiveness (Section 7.11.5) because of the extensive upland and in-water construction upland and in-water activities occurring over a multi-year period; however, the alternative is rated “high” for Long-Term Effectiveness and Permanence (Section 7.11.3) because all PTWs are removed or treated. It also complies with all ARARs, with some uncertainty about achieving MCLs for all

COCs; however, because all PTWs are addressed, it would be a candidate for an ARAR waiver (Section 7.11.2).

7.11.2 *Compliance with ARARs*

As discussed in Section 7.1.1.2, Alternative 9 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with uncertainty about meeting the requirements of the SDWA, which requires achievement of groundwater MCLs throughout the Site plume. Because all PTW sources are removed, Alternative 8 could substantially meet all or most MCLs if not completely. The extent to which MCLs would be achieved in this alternative is discussed below.

7.11.2.1 Compliance with the MCL ARAR

For Alternative 9, groundwater volume exceeding MCLs is predicted to decrease by 97 percent for benzene, 81 percent for benzo[a]pyrene, and 21 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 9, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by roughly 78 percent relative to the No Action alternative. As discussed in Section 7.1.1.2, EPA views the groundwater modeling results as conservative such that Alternative 9 would either minimize or eliminate the size of the contaminated plume for one or more of the COCs with MCLs within a reasonable timeframe.

7.11.2.2 Technical Impracticability Waiver

It is uncertain whether Alternative 9 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is assumed that a TI waiver would be granted if monitoring data indicate that MCLs may not be met, since all known PTWs and contaminated soil and sediment would be addressed under this alternative.

7.11.2.3 Alternative 9 Rating with Respect to this Criterion

Alternative 9 satisfies the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will either be met throughout the plume or a TI waiver may be granted.

7.11.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 9 is evaluated in this section with respect to the magnitude of residual risks and adequacy/reliability of controls.

7.11.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

- For Alternative 9, none of the PTW is left in place as untreated waste. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBC are reduced (benzene at 97 percent, naphthalene at 86 percent, benzo[a]pyrene at 81 percent, and arsenic at 21 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur, until COCs are returned to acceptable levels.

7.11.3.2 Adequacy and Reliability of Controls

Controls in Alternative 9 include an upland cap, engineered sand caps, reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. An upland cap may not be needed once all PTW and soil contributing to MCL exceedances has been addressed.

Engineered Sand Caps. Same as Alternatives 7 and 8, except some institutional controls may not be needed in perpetuity because of significant contaminant mass flux reduction because all PTW and sediment contributing to MCL exceedances is being addressed.

Reactive Residuals Cover. Same as Alternatives 7 and 8 except all PTW and sediment contributing to MCL exceedances is dredged, therefore the areal extent of reactive residual covers is extended.

ENR. Same as Alternatives 7 and 8.

Institutional Controls. Same as Alternatives 7 and 8 except some institutional controls may not be needed in perpetuity (Table 7-3 lists the institutional controls and associated long-term monitoring that may be implemented in Alternative 9).

7.11.3.3 Alternative 9 Rating with Respect to this Criterion

Alternative 9 is rated “high” with respect to long-term effectiveness and permanence because of its reliance on treatment and removal technologies to address contaminated soil and sediment, including all PTWs.

7.11.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.11.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 9 include a reactive residuals cover, upland DNAPL/soil *in situ* stabilization, and on-site thermal treatment. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes. This alternative would treat all PTWs at the Site.

7.11.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 9, approximately 104,400 gallons of DNAPL are treated by *in situ* stabilization; approximately 340,700 gallons of DNAPL are removed and thermally treated onsite. The amount of contaminated groundwater treated due to dewatering for excavation is unknown but is expected to be significant. The amount of contaminated groundwater treated by sorption onto reactive residual covers is unknown but expected to be minimal.

7.11.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 9 would reduce the mobility of upland DNAPL, through *in situ* stabilization, by approximately 104,400 gallons or 23 percent of the total DNAPL on-site; however, the toxicity and volume of the treated material would not be reduced. The remaining 77 percent would be removed from the upland and aquatic environment via excavation and dredging and would be treated thermally on-site, which would reduce the toxicity, mobility, and volume of the DNAPL.

DNAPL/soil thermal treatment would reduce the volume and mobility of contaminated groundwater. Based on modeling, the mass reduction of benzene, naphthalene, benzo(a)pyrene, and arsenic plumes in groundwater would be 99, 100, 99, and 29 percent, respectively. The mass flux reduction for benzene, naphthalene, benzo(a)pyrene, and arsenic would be reduced by 100, 100, 100, and 62 percent, respectively (see Figure 7-3).

The degree of expected reductions in toxicity, mobility, and volume from the reactive residual covers is the same as for Alternative 8, except the area would be larger.

7.11.4.4 Degree to which Treatment is Irreversible

The vast majority of DNAPL in the solidified soil is expected to be treated and solidification treatment would be expected to be essentially irreversible. Thermal treatment is irreversible as well. Dissolved-phase COCs (benzene and volatile PAHs) that may leach from the solidified block can be assumed to not be irreversibly treated.

Treatment of DNAPL and dissolved constituents using reactive residual covers containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, the quantities that would be sorbed are unknown.

7.11.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL-impacted soil and sediment thermally treated would remain onsite, and mixed with the soil/sediment matrix would comprise approximately 515,600 cy. DNAPL treated by ISS would remain onsite, and mixed with the soil matrix would comprise approximately 362,900 cy. The solidified matrix is not considered to be post-treatment residual or untreated waste; whereas dissolved contaminants in groundwater that may leach and migrate out of the solidified matrix from DNAPL would be considered untreated or residual post-treatment waste. The amount of residual dissolved-phase contamination that may leach is unknown.

7.11.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 9 satisfies the statutory preference for treatment as a primary component of the alternative because the majority of the alternative includes treatment.

7.11.4.7 Alternative 9 Rating with Respect to this Criterion

Alternative 9 is rated “high” with respect to reduction of toxicity, mobility, or volume through treatment because the vast majority of the Site contamination would be treated, including all PTWs.

7.11.5 *Short-Term Effectiveness*

Alternative 9 has many of the same activities as Alternatives 7 and 8. Alternative 9 involves a combination of solidification and excavation and on-site thermal treatment of DNAPL-impacted and contaminated soil. All DNAPL-impacted sediment is dredged and treated on-site.

7.11.5.1 Protection of Community during Remedial Actions

For Alternative 9, potential exposure to hazardous substances to the neighboring community may result from:

1) inhalation exposure to vapors from during dredging of 173,100 cy of potentially contaminated sediment;
2) inhalation exposure to dust and vapors from excavation of 22,000 cy of DNAPL-impacted soil;
3) inhalation exposure to dust or air emissions from handling and stockpiles for on-site thermal treatment, of 515,600 cy of potentially contaminated soils/sediment (80,300 cy of DNAPL-impacted soils/sediment);
4) inhalation exposure to dust and vapors from *in situ* solidification of 8,400 cy of DNAPL-impacted soil; and
5) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean or reactive material to cap/cover 29.4 acres of sediment.

Alternative 9 involves excavation 22,000 cy of shallow DNAPL-impacted soils as opposed to 30,500 cy of shallow and deep DNAPL-impacted soils with Alternative 8. Therefore, in Alternative 9, slightly less DNAPL-impacted soil would be excavated in Alternative 8 and a small amount of DNAPL-impacted soil will be solidified unlike in Alternative 8. Potential risk from dust generated from excavation is expected to about the same as Alternative 8.

Alternative 9 involves dredging of 173,100 cy of sediment; however approximately 58,300 cy represent DNAPL-impacted sediment; therefore, the amount of DNAPL-impacted sediment dredged for Alternative 9 is the same as for Alternatives 7 and 8. The additional contaminated sediment dredged as part of Alternative 9 is not impacted by DNAPL and is expected to have much lower contaminant concentrations.

Implementation of Alternative 9 will include on-site thermal treatment of fewer DNAPL-impacted soils and the same DNAPL-impacted sediment as Alternative 8, but the overall volume of thermally-treated soil and sediment is approximately 515,600 cy, as compared to 268,400 cy for Alternative 8. However, the additional soils and sediment treated would have much lower levels of contamination than the DNAPL-impacted soils and sediment, so there would be less concern for air emissions exceeding safe levels.

Alternative 9 is not expected to cause unacceptable risks to the community because of the availability of the protective procedures and enforceable requirements. Safe levels of exposure to hazardous substances will be identified from existing regulations or risk-based calculations and included in Site operation plans. Continuous monitoring for COCs for all appropriate on-site activities, such as thermal treatment and excavation will be required and overseen by EPA personnel.

Impacts to "quality of life" are assumed to be a concern of the neighboring community.

Alternative 9 would require similar protective measures as those identified under Alternatives 7 and 8.

7.11.5.2 Protection of Workers during Remedial Actions

For Alternative 9, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation exposure to vapors from during dredging of 173,100 cy of potentially contaminated sediment;
2) inhalation and dermal exposure to dust and vapors from excavation of 22,000 cy of DNAPL-impacted soil;
3) inhalation and dermal exposure to dust or air emissions from handling and stockpiles for on-site thermal treatment, of 515,600 cy of potentially contaminated soils/sediment (80,300 cy of DNAPL-impacted soils/sediment);
4) inhalation and dermal exposure to dust and vapors from *in situ* solidification of 8,400 cy of DNAPL-impacted soil; and
5) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean or reactive material to cap/cover 29.4 acres of sediment.

Alternative 9 involves a combination of *in situ* solidification and excavation of the same DNAPL-impacted soils as Alternatives 7 and 8, with the majority being excavated. Potential risk to workers from dust and vapors generated from excavation is expected to about the same as Alternative 8. The use of appropriate protective clothing, equipment, such as dust masks, and BMPs would be expected to mitigate potential risks associated with dust containing contaminated soil.

The overall volume of thermally-treated soil and sediment is approximately 515,600 cy, as compared to 268,400 cy for Alternative 8. However, the additional soils and sediment treated would have much lower levels of contamination than the DNAPL-impacted soils and sediment, so there would be less concern for air emissions exceeding safe levels. Worker exposure can be mitigated by use of protective clothes/gear, engineering controls, and use of BMPS, as will be specified in the site safety plan and enforced by EPA. Construction Quality Assurance and Control Plans will be required. One focus of these plans is the prevention of worker exposure to contaminated media by direct contact or by the inhalation route.

Similar measures to protect workers in Alternatives 7 and 8 will also be used with Alternative 9.

7.11.5.3 Environmental Impacts

The environmental impacts of Alternative 9 would be similar to Alternatives 7 and 8, except a larger portion of the nearshore aquatic habitat would be dredged as opposed to capped. The area of sediments either dredged and/or capped/covered is the same throughout all the alternatives; however, dredging can result in the generation of contaminated residuals. The use of a residuals cover, which will mitigate the impact of residuals, will less adversely impact the aquatic environment than RCM caps used in previous alternatives.

Impacts to the environment from the uplands is expected to increase as compared to Alternative 8 because a larger area would be subject to excavation/solidification.

7.11.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 11 years from initiation of remedial construction, longer than Alternative 8 by approximately 7 years (Figure 7-5). Not all RAOs would be achieved at the end of the construction period. The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would require an unknown period of time to be met following the end of construction; however, it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver would be granted, if necessary. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.11.5.5 Alternative 9 Rating with Respect to this Criterion

Alternative 9 is rated “low” with respect to short-term effectiveness. A portion of the upland DNAPL-impacted soil will be treated with in situ solidification; but the majority of the DNAPL-impacted soil will be excavation, similar to Alternative 8. There is no change in the amount of DNAPL-impacted sediment to be dredged. However, much larger volumes of potentially contaminated soil and sediment will be handled, stockpiled and will undergo on-site thermal treatment, which may cause of higher concern for worker exposure. No unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. Impacts to the aquatic environment are expected to be similar to Alternatives 7 and 8, except a larger portion of the nearshore aquatic environment is dredged and a smaller portion is subject to an engineered sand cap.

7.11.6 *Implementability*

7.11.6.1 Technical Feasibility

Alternative 9 only includes many of the same remedial technologies that have been incorporated into Alternatives 7 and 8, including on-site thermal treatment. Specifically, Alternative 9 consists of: 1) placing and repair/placement of engineered sand caps and ENR cover; 2) dredging 58,300 cy of DNAPL-impacted sediments along with 114,800 cy of potentially contaminated sediment; 3) solidification of 8,400 cy of DNAPL-impacted soils; 4) excavation of 22,000 cy of DNAPL-impacted soil along with 320,500 cy of potentially contaminated soil; and 5) on-site thermal treatment and backfill of 515,600 cy of partially contaminated soil and sediment. An upland soil cap may not be required depending on the post-treatment sampling results of the thermally treated soil and sediment to be used as backfill. Alternative 9 incorporates a number of construction elements; however, they are proven and commonly used technologies such as solidification, excavation, dredging, and thermal treatment. Excavation as conducted in Alternative 9, may present some implementability challenges just due to the size of the area to be excavated, in the dry, requiring extensive shoring and dewatering systems. Thermal treatment is also anticipated to pose technical feasibility challenges as explained in Alternative 8.

7.11.6.2 Administrative Feasibility

Same as Alternatives 7 and 8.

7.11.6.3 Availability of Services and Materials

Same as Alternatives 7 and 8, except for more extensive sheet piles for excavation shoring.

7.11.6.4 Alternative 9 Rating with Respect to this Criterion

Alternative 9 is rated “low” with respect to implementability because of the extensive amount of partially contaminated soil and sediment that will be thermally treated and dewatered on-site.

7.11.7 *Cost*

The estimated present worth cost of Alternative 9 is $262 million, including a projected $259 million for capital construction and $2.7 million (present worth) for OM&M.

7.12 Detailed Evaluation of Alternative 10

Alternative 10 includes removal of soil and sediment that is likely to act as a source of groundwater contamination above MCLs, including PTWs and soils contaminated with recalcitrant compounds (e.g., arsenic and benzo[a]pyrene). Contaminated soil and groundwater in the Deeper Alluvium would be treated by groundwater pump and treat to accelerate the groundwater restoration timeframe. The purpose of Alternative 10 is to remove PTWs and to restore groundwater to the maximum extent possible within the shortest timeframe.

7.12.1 *Overall Protection of Human Health and the Environment*

Alternative 10 would eliminate, reduce, or control the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment (see Sections 4.2.2 and 4.2.3, respectively) as follows:

7.12.1.1 RAOs for Protection of Human Health

- **HH1: Restore Groundwater to its Highest Beneficial Use by Meeting MCLs and RBC for Drinking Water.** The restoration of groundwater to its highest beneficial use (drinking water) may be achieved by Alternative 10. It is the intent to address 100 percent of the PTW that causes the groundwater contamination in this alternative, and remove Shallow Aquifer materials outside the DNAPL footprint where benzo(a)pyrene and arsenic exceed MCLs. Overall, the groundwater plume would be reduced by 93 percent as compared to Alternative 1 (No Action).[19] Human health risks would be addressed in the same manner as Alternative 2 until COCs are reduced to acceptable levels.

- **HH2: Reduce Recreational and Subsistence Ingestion of Seafood to Acceptable Levels.** Same as Alternative 9.
- **HH3: Reduce Recreational Beach Users Risk to Surface Sediment to Acceptable Levels.** Same as Alternative 9.
- **HH4: Reduce Recreational Beach Users Risk to Surface Water to Acceptable Levels:** Same as Alternative 9.
- **HH5: Reduce Risk to Indoor Vapors to Acceptable Levels:** Human health risk from inhalation of vapors, in enclosed spaces, from groundwater and/or soils contaminated with COCs would be mitigated by excavation of all contaminated soil.
- **HH6: Reduce Risk to Future Residents, Commercial Workers, and Excavation/Construction Workers from Soil to Acceptable Levels.** Human health risk from direct contact or incidental ingestion of COCs in soil would be mitigated by addressing all contaminated soil. A total of approximately 705,400 cy of DNAPL and soil would be excavated and thermally treated on-site.

7.12.1.2 RAOs for Protection of the Environment

- **EP1: Reduce Risk to Aquatic Plants and Fish from Surface Water to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.
- **EP2: Reduce Risk to Terrestrial Plants, Birds, and Mammals from Contact with Soil to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.
- **EP3: Reduce Risk to Aquatic-dependent Birds, Mammals, and Benthic Community from Sediment to Acceptable Levels.** Same as Alternative 8, except the extent of dredging goes beyond DNAPL areas to include the additional nearshore area where sediment is potentially contributing to MCL exceedances.

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[19] See Section 7.8.2.1 for a discussion of the uncertainty of modeling results, particularly for Alternatives 7 through 10 that address all PTW source materials.

7.12.1.3 Alternative 10 Rating with Respect to this Criterion

Alternative 10 satisfies the threshold criterion for Overall Protection of Human Health and the Environment. It is rated “low” for Short-Term Effectiveness (Section 7.12.5) because of the extensive upland and in-water construction upland and in-water activities occurring over a multi-year period; however, the alternative is rated “high” for Long-Term Effectiveness and Permanence (Section 7.12.3) because all PTWs are removed or treated. It also complies with all ARARs, with some uncertainty about achieving MCLs for all COCs; however, because all PTWs are addressed, it would be a candidate for an ARAR waiver (Section 7.12.2).

7.12.2 *Compliance with ARARs*

As discussed in Section 7.1.1.2, Alternative 10 would comply with the chemical-specific, action-specific, and location-specific ARARs and TBCs identified in Section 4 (see Tables 4-1 through 4-3) with uncertainty about meeting the requirements of the SDWA, which requires achievement of groundwater MCLs throughout the Site. Because all PTW sources are removed, Alternative 10 could substantially meet all or most MCLs if not completely. The extent to which MCLs would be achieved in this alternative is discussed below.

7.12.2.1 Compliance with MCL ARAR

For Alternative 10, groundwater volume exceeding MCLs is predicted to decrease by 100 percent for benzene and benzo[a]pyrene, and 65 percent for arsenic relative to the No Action alternative 100 years after remedial construction completion (see Figure 7-1).

Refer to Section 7.1.1.2 and Appendix A for discussion of the groundwater modeling performed to predict progress toward achieving MCLs under each remedial alternative. One hundred years after remedial construction completion for Alternative 10, the groundwater volume exceeding MCLs in the aggregate was predicted to decrease by roughly 91 percent relative to the No Action alternative. Among the individual COCs modeled, the model predicted a 65 percent decrease for arsenic after 100 years, complete aquifer restoration for benzene 14 years after remedy construction, and complete aquifer restoration for benzo(a)pyrene upon completion of construction. As discussed in Section 7.1.1.2, EPA views the groundwater modeling results as conservative such that Alternative 10 would either minimize or eliminate the size of the contaminated plume for one or more of the COCs with MCLs within a reasonable timeframe.

7.12.2.2 Technical Impracticability Waiver

It is uncertain whether Alternative 10 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is assumed that a TI waiver would be granted if monitoring data indicate that MCLs may not be met, since all known PTWs and contaminated soil and sediment would be addressed under this alternative.

7.12.2.3 Alternative 10 Rating with Respect to this Criterion

Alternative 10 satisfies the threshold criterion for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will either be met throughout the plume or a TI waiver may be granted.

7.12.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence of Alternative 10 is evaluated in this section with respect to magnitude of residual risks and adequacy/reliability of controls.

7.12.3.1 Magnitude of Residual Risks

In this subsection, residual risks associated with untreated waste/treatment residuals left on-site after remediation is presented in terms of the degree to which sources are remediated and the percent the plume is reduced.

For Alternative 10, none of the PTW is left in place as untreated waste. The dissolved-phase plumes exceeding the MCL ARARs and drinking water RBC are reduced (benzene, naphthalene, and benzo[a]pyrene at 100 percent, and arsenic at 65 percent) from the Alternative 1 (No Action) baseline volume. Unacceptable risks remain in place should exposure occur, until COCs are returned to acceptable levels.

7.12.3.2 Adequacy and Reliability of Controls

Controls in Alternative 10 include an upland cap, engineered sand caps, reactive residuals cover, ENR, and institutional controls. The adequacy and reliability of each of these controls are discussed below.

Upland Cap. An upland cap may not be needed once all PTW and soil contributing to MCL exceedances has been addressed.

Engineered Sand Caps. Same as Alternative 9.

Reactive Residuals Cover. Same as Alternative 9.

ENR. Same as Alternative 9.

Institutional Controls. Same as Alternative 9, except some institutional controls (related to activities that may be restricted in *in situ* solidification areas) would not be needed. Table 7-3 lists the institutional controls and associated long-term monitoring that may be implemented in Alternative 10.

7.12.3.3 Alternative 10 Rating with Respect to this Criterion

Alternative 10 is rated "high" with respect to long-term effectiveness and permanence because of its reliance on removal technologies to address contaminated soil and sediment, including all PTWs.

7.12.4 *Reduction of Toxicity, Mobility, or Volume Through Treatment*

7.12.4.1 Treatment Processes Used and Materials Treated

Treatment processes used in Alternative 10 include a reactive residuals cover, on-site thermal treatment, and treatment of extracted groundwater. This alternative would treat all PTWs at the Site. Refer to Table 7-2 and Figure 7-2 for estimated DNAPL treatment volumes.

7.12.4.2 Amount of Hazardous Materials Destroyed or Treated

Under Alternative 10, approximately 445,100 gallons of DNAPL are removed and thermally treated onsite. The intent of this alternative is to treat all PTWs at the Site, as well as soils contaminated with recalcitrant compounds. The amount of soil contaminants treated is unknown, but the mass in contaminated soil is expected to be negligible compared to the DNAPL.

Alternative 10 also includes a groundwater treatment system that would be designed for treatment of dissolved contaminants only, not DNAPL. Because the vast majority of contaminant mass at the Site is present as DNAPL, the relative contaminant mass present in the dissolved phase that would be treated via groundwater treatment would be negligible. The amount of groundwater contaminants treated due to dewatering for excavation is unknown. The amount of groundwater contaminants treated during ongoing pump and treat operations is also unknown.

7.12.4.3 Degree of Expected Reductions in Toxicity, Mobility, and Volume

Alternative 10 would reduce the toxicity, mobility, and volume of DNAPL via on-site thermal treatment, which volatilizes the organic compounds.

DNAPL/soil thermal treatment and groundwater extraction would reduce the volume and mobility of contaminated groundwater. Groundwater treatment via GAC would also reduce the mobility of organic contaminants as they would be sorbed to the GAC; however GAC has limited effectiveness for treating arsenic.

Based on modeling, the mass reduction of benzene and naphthalene would be 100 percent, for benzo(a)pyrene would be 99 percent, and for arsenic would be 53 percent. Mass flux for the organic COCs was projected to be negligible (essentially 100 percent reduction), whereas projected reduction in arsenic mass flux was approximately 86 percent relative to the No Action alternative (see Figure 7-3).

The degree of expected reductions in toxicity, mobility, and volume from the reactive residual covers is the same as for Alternative 9.

7.12.4.4 Degree to which Treatment is Irreversible

Organic contaminant thermal treatment is irreversible. Treatment of organic contaminants in groundwater using GAC would also be irreversible.

Treatment of DNAPL and dissolved constituents in the aquatic environment using reactive residual covers containing organoclay would be irreversible by sorption of organic matter to the treatment material. At present, the quantities that would be sorbed are unknown.

7.12.4.5 Type and Quantity of Residuals Remaining after Treatment

DNAPL-impacted soil and sediment thermally treated on-site would remain onsite, and mixed with the soil/sediment matrix would comprise approximately 878,500 cy.

Organic contaminants would effectively adsorb onto GAC until the GAC becomes loaded. Treatment system monitoring would be conducted to determine when GAC replacement is required. GAC replacement would generate spent carbon, which would be transported off site for reactivation or disposal.

7.12.4.6 Whether the Alternative Would Satisfy the Statutory Preference for Treatment as a Principal Element.

Alternative 10 satisfies the statutory preference for treatment as a primary component of the alternative because the majority of the alternative includes treatment.

7.12.4.7 Alternative 10 Rating with Respect to this Criterion

Alternative 10 is rated "high" with respect to reduction of toxicity, mobility, or volume through treatment. The vast majority of the Site contamination would be treated, including all PTWs.

7.12.5 *Short-Term Effectiveness*

Alternative 10 is similar to Alternative 9 except all upland contaminated soil is excavated and treated on-site, whereas for Alternative 9, deeper DNAPL-impacted and contaminated soils are treated with in situ stabilization. The offshore remedy components for Alternative 10 are identical to Alternative 9.

7.12.5.1 Protection of Community during Remedial Actions

For Alternative 10, potential exposure to hazardous substances to the neighboring community may result from:

6) inhalation exposure to vapors from during dredging of 173,100 cy of potentially contaminated sediment;
7) inhalation exposure to dust and vapors from excavation of 30,500 cy of DNAPL-impacted soil;
8) inhalation exposure to dust or air emissions from handling and stockpiles for on-site thermal treatment, of 878,500 cy of potentially contaminated soils/sediment (88,800 cy of DNAPL-impacted soils/sediment); and
9) inhalation of vapors or air emissions from an onsite groundwater pumping and treatment system; and
10) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean or reactive material to cap/cover 29.4 acres of sediment.

Alternative 10 involves excavation 30,500 cy of DNAPL-impacted soils as opposed to 22,000 cy of shallow DNAPL-impacted soils with Alternative 9. Therefore, in Alternative 10, more DNAPL-impacted soil would be excavated in Alternative 9 (and no DNAPL-impacted soil will be solidified as in Alternative 9. Potential risk from dust generated from excavation is expected to about the same as Alternative 9.

Alternative 9 involves the same dredging of 173,100 cy of sediment (including 58,300 cy of DNAPL-impacted sediment). Therefore, potential exposures to vapors during dredging are identical to Alternative 9.

Alternative 10 also includes construction and operation of a groundwater pumping and treatment system; although these systems are commonly used and not expected to pose any risks to the community.

Implementation of Alternative 10 will include on-site thermal treatment of more DNAPL-impacted soils and the same DNAPL-impacted sediment as Alternative 9, but the overall volume of thermally-treated soil and sediment is approximately 878,500 cy, as compared to 515,600 cy for Alternative 9. However, the additional soils and sediment treated would have much lower levels of contamination than the DNAPL-impacted soils and sediment, so there would be less concern for air emissions exceeding safe levels.

Alternative 10 is not expected to cause unacceptable risks to the community because of the availability of the protective procedures and enforceable requirements. Safe levels of exposure to hazardous substances will be identified from existing regulations or risk-based calculations and included in Site operation plans. Continuous monitoring for COCs for all appropriate on-site activities, such as thermal treatment and excavation will be required and overseen by EPA personnel.

Impacts to "quality of life" are assumed to be a concern of the neighboring community.

Alternative 10 would require similar protective measures as those identified under Alternatives 7 through 9.

7.12.5.2 Protection of Workers during Remedial Actions

For Alternative 10, potential exposure to hazardous substances to on-site workers may result from:

1) inhalation exposure to vapors from during dredging of 173,100 cy of potentially contaminated sediment;
2) inhalation and dermal exposure to dust and vapors from excavation of 30,500 cy of DNAPL-impacted soil;
3) inhalation and dermal exposure to dust or air emissions from handling and stockpiles for on-site thermal treatment, of 878,500 cy of potentially contaminated soils/sediment (88,800 cy of DNAPL-impacted soils/sediment);
4) inhalation of vapors or air emissions from an onsite groundwater pumping and treatment system; and
5) inhalation of the same amount of dust generated, as with all other alternatives, from the import and handling of clean or reactive material to cap/cover 29.4 acres of sediment.

Alternative 10 involves excavation and dredging of the same DNAPL-impacted soils and sediment as Alternative 8. Potential risk to workers from dust and vapors generated from excavation is expected to about the same as Alternatives 8 and 9. The use of appropriate protective clothing, equipment, such as dust masks, and BMPs would be expected to mitigate potential risks associated with dust containing contaminated soil.

Alternative 10 also includes construction and operation of a groundwater pumping and treatment system; although these systems are commonly used and not expected to pose any unacceptable risks to the workers that could not be mitigated by protective gear and protocols.

The overall volume of thermally-treated soil and sediment is approximately 878,500 cy, as compared to 515,600 cy for Alternative 9. However, the additional soils and sediment treated would have much lower levels of contamination than the DNAPL-impacted soils and sediment, so there would be less concern for air emissions exceeding safe levels. Worker exposure can be mitigated by use of protective clothes/gear, engineering controls, and use of BMPS, as will be specified in the site safety plan and enforced by EPA. Construction Quality Assurance and Control Plans will be required. One focus of these plans is the prevention of worker exposure to contaminated media by direct contact or by the inhalation route.

Similar measures to protect workers in Alternatives 7 through 9 will also be used with Alternative 10.

7.12.5.3 Environmental Impacts

The environmental impacts of Alternative 10 would be the same as Alternative 9.

7.12.5.4 Time until Remedial Action Objectives are Achieved

Remedial construction and establishment of institutional controls would be expected to be completed in about 12 to 13 years from initiation of remedial construction, two years longer than Alternative 9 (Figure 7-5). Not all RAOs would be achieved at the end of the construction period. The RAO to restore groundwater to its highest beneficial use by meeting MCLs and RBCs for drinking water would require an unknown period of time to be met following the end of construction; however, it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver would be granted, if necessary. The RAOs to reduce risks to humans and wildlife from consumption of fish/shellfish containing unacceptable levels of cPAHs is also not expected to be met immediately, although dredging, caps and ENR will provide for a “clean” sediment surface and will reduce aquatic biota concentrations. However, seafood and aquatic wildlife that have already accumulated cPAHs will not be safe to consume. All other RAOs involving reduction of risk via direct contact with contaminated media would be met at the end of the construction period.

7.12.5.5 Alternative 10 Rating with Respect to this Criterion

Alternative 10 is rated “low” with respect to short-term effectiveness. There is no change in the amount of DNAPL-impacted soil and sediment to be excavated or dredged as compared with Alternative 8; however, much larger volumes of potentially contaminated soil and sediment will be handled, stockpiled and will undergo on-site thermal treatment, which may cause of higher concern for worker exposure. No unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. Impacts to the aquatic environment will be identical to Alternative 9.

7.12.6 *Implementability*

7.12.6.1 Technical Feasibility

Alternative 10 includes the same remedial technologies that have been incorporated into Alternatives 9, with the exception of solidification of DNAPL-impacted soil. Specifically, Alternative 10 consists of: 1) placing and repair/placement of engineered sand caps and ENR cover; 2) dredging of 58,300 cy of DNAPL-impacted sediments along with 114,800 cy of potentially contaminated sediment; 3) excavation of 30,500 cy of DNAPL-impacted soil along with 674,900 cy of potentially contaminated soil; and 4) on-site thermal treatment and backfill of 878,500 cy of partially contaminated soil and sediment. An upland soil cap may not be required depending on the post-treatment sampling results of the thermally treated soil and sediment.

The conceptual shoring system for Alternative 10 would include 95-foot-long sheet piles (based on the analysis performed in Section 6), which are not readily available and could result in transportation challenges.

Technical feasibility concerns for Alternative 10 are the same as Alternative 9 with the exception of on-site solidification.

7.12.6.2 Administrative Feasibility

Same as in Alternative 9.

7.12.6.3 Availability of Services and Materials

Same as Alternative 9.

7.12.6.4 Alternative 10 Rating with Respect to this Criterion

Alternative 10 is rated “low” with respect to implementability because of the extensive amount of partially contaminated soil and sediment that will be thermally treated and dewatered on-site and the transport of custom made sheet pile to be used as shoring for excavation.

7.12.7 *Cost*

The estimated present worth cost of Alternative 10 is $409 million, including a projected $380 million for capital construction and $29 million (present worth) for OM&M (primarily associated with the groundwater pump-and-treat system).